

**UNIVERSITY OF HAWAII
TELESCOPES AT
MAUNA KEA OBSERVATORY**

USER MANUAL

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Chapter 1

INTRODUCTION

1.1 General

This Manual is intended to assist astronomers wishing to use the University of Hawaii (UH) facilities at Mauna Kea Observatory (MKO). These telescopes are run primarily as university research facilities (rather than visitor facilities). However, proposals to study Solar system objects with the 2.2-m telescope are welcomed from investigators external to the University of Hawaii. Proposals to use the 2.2-m telescope to study objects beyond the Solar system which have Principal Investigators external to the University of Hawaii, are not normally considered eligible for consideration by the Time Allocation Committee. External proposals for the 61-cm telescope will only be considered under special circumstances.

The UH telescopes are operated by the Institute for Astronomy (IfA) of the University of Hawaii. Institute headquarters are located on the University campus in Honolulu, on the Island of Oahu. A map showing the route from Honolulu airport to the Institute for Astronomy is shown in Figure 1.1. The telescopes are located at the Observatory on the summit of Mauna Kea on the Big Island of Hawaii—about a 2 hour drive from Hilo (see maps below).

The University of Hawaii's 2.2-meter telescope is located at Mauna Kea Observatory, at an altitude of 4,214 m (13,824 ft), latitude $+19^{\circ}49'34''$, and longitude $155^{\circ}28'20''$ ($10^{\text{h}}21^{\text{m}}53^{\text{s}}$) West.

1.2 About this Manual

Because of the cost and time involved in producing printed versions of this manual, the printed version will be updated relatively infrequently. However, we intend to keep the on-line version of this manual updated as changes occur. This most up-to-date version of the manual will be accessible from the World Wide Web. The URL of the home page for the 2.2-meter telescope is:

<http://www.ifa.hawaii.edu/88inch>

and the URL for this manual is:

<http://www.ifa.hawaii.edu/88inch/manuals/user.pdf>.

Also available from the home page are numerous instrument manuals, which contain more in-depth information.

1.3 Observing Time—Policy and Procedures

Requests for the use of UH facilities at MKO should be made to the Director of the IfA as far in advance as possible. Scheduling periods (six-month semesters) and the deadlines for receipt of observing requests are shown in Table 1.1. If the deadline falls on a weekend or holiday, proposals are due on the *next* working day.

As the UH telescopes are not supported primarily as visitor facilities, the Director suggests that only experienced observers apply for telescope time. Those asking for time on the 61-cm telescope should be thoroughly familiar with similar instrumentation at other sites.

Because of staff limitations, the maximum observing time per night is normally 11 hours. Observing beyond 11 hours is only possible with the agreement of the Telescope Operator, and should be negotiated in advance (it must not be taken for granted). The 11 hour observing period normally commences around sunset, but can be adjusted to some extent, to suit the observer's requirements, by negotiation with the Telescope Operator. Daytime observing with the 2.2-m telescope is normally not possible.

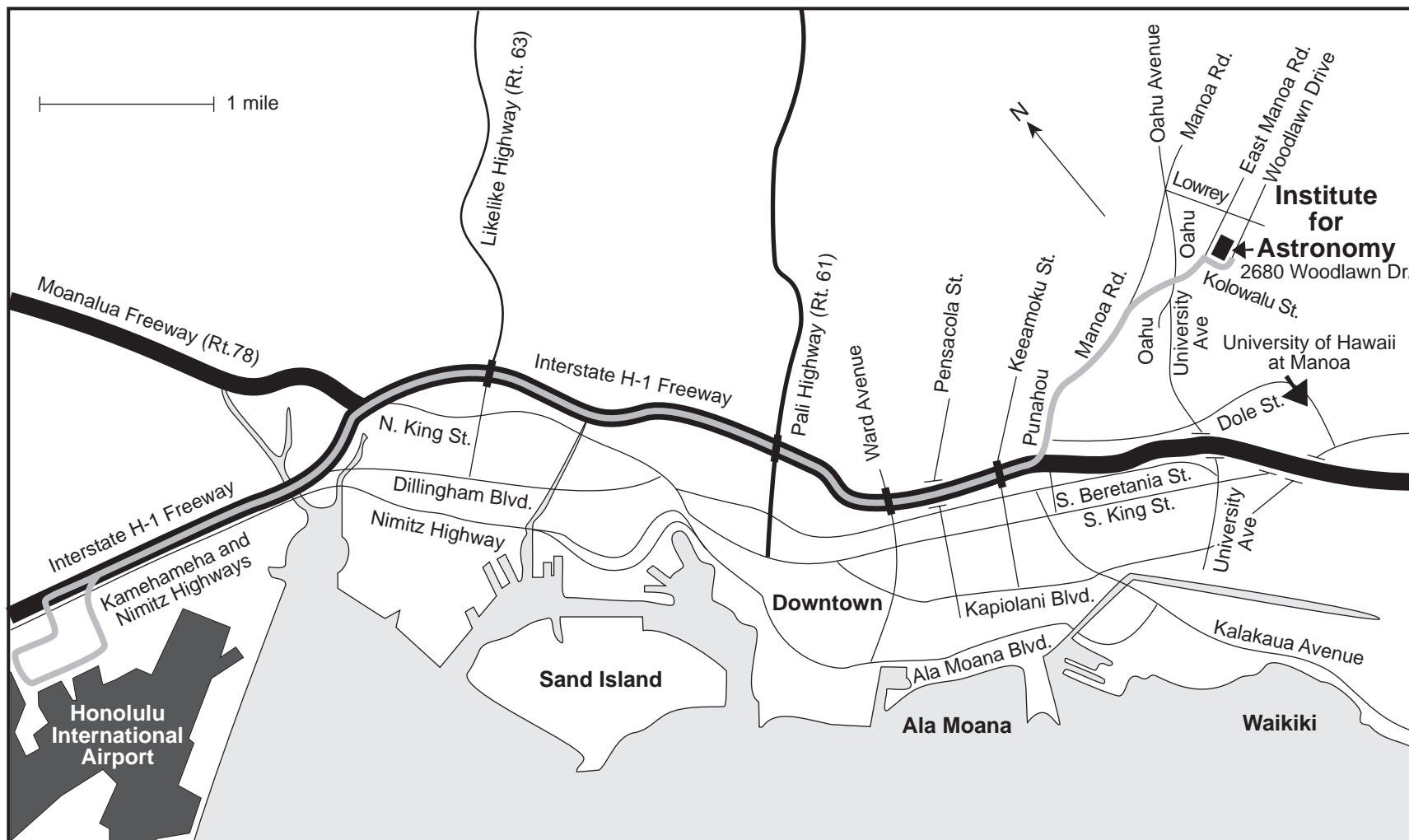


Figure 1.1: The location of the Institute for Astronomy in Honolulu

Table 1.1: Due dates for UH Observing Requests

Observing Period	Due Date
February–July	September 15
August–January	March 15

Applications are to be made on a standard “Observing Time Request” form, a copy of which may be found in Appendix B. This form was constructed using the \LaTeX typesetting program; the applicant can insert the required information into the source file and subsequently print the completed application. Electronic copies of the “Observing Time Request” form may be obtained from the URL listed in Section 1.2. Applicants must limit their scientific justification to one page of text. An additional page of figures may be included. References do not count against the page limit.

Successful applicants are informed of their assigned observing time about 4 weeks before the beginning of the semester in which their observing run occurs. Any changes which are substantially different from the proposed observing program or personnel changes from those listed in the original application must be approved by the Director.

1.3.1 Students and Assistants

Students and assistants may accompany visiting observers, but because of limited accommodations at the mid-level facility, special permission must be requested on the “Observing Time Request” form if the total number exceeds three. Assistants sent to observe in place of the principal scientist will not be accepted unless it is made clear that full collaboration in research and joint authorship in publication is intended. The granting of observing time to visiting observers and their students does not imply an obligation on the part of the Institute for Astronomy to continue granting time in order for students to complete their thesis research.

1.3.2 Information before Arrival

If observing time is granted, each visiting observer is required to complete the on-line “Visiting Observer Information Form” at <http://www.ifa.hawaii.edu/cgi-bin/visitingobserver.form> at least 3 weeks before his/her scheduled arrival. If any equipment is going to be sent to the telescope, this should be directly coordinated with the UH Telescope Superintendent.

1.3.3 Colloquia

We may ask observers to whom we have granted time on the 2.2-m telescope to spend a day in Honolulu, either before or after their observing run, to present a colloquium and discuss their research with staff of the Institute for Astronomy.

1.3.4 Reports to the Director

Visiting observers will be requested to send a letter report to the Director setting out any comments about the observing conditions and the observer’s overall reaction to the operation of the facility. In addition, a short “Observing Report” form (included in Appendix B) should be submitted to the Telescope Manager.

1.3.5 Publications and Acknowledgments

It is expected that the results of observations made using UH facilities at MKO will be published in the scientific literature. All publications based principally on research results obtained with the University facilities shall carry a credit line and footnote of the following form:

Title, Author[†], Home Institution

and, as a footnote: [†] Visiting observer, (named telescope) at Mauna Kea Observatory, Institute for Astronomy, University of Hawaii.

Visiting observers who use the UH facilities at MKO for only a small part of a larger program should include a substantial acknowledgment to the University of Hawaii in their publication. Two preprints and five reprints of papers resulting from any observational work carried out on UH telescopes should be sent to the Director of the IfA.

1.4 Newsletter

A telescope newsletter is produced two times per year, about three weeks before the telescope deadline. This newsletter contains updates on instruments and detectors, and serves as a supplement to this manual. The newsletter is distributed both via electronic mail and via regular mail. Requests for inclusion on the newsletter mailing list should be sent electronically to 88inch@ifa.hawaii.edu.

1.5 Information for Visiting Observers

The international airport of Honolulu on the island of Oahu is served regularly by major airlines; regular and frequent interisland flights connect Honolulu with Hilo on the big island of Hawaii, as well as with other islands of the State of Hawaii (see Fig. 1.2).

Visiting observers should make their own hotel, airline, car rental, etc., arrangements, as the responsibilities of the Institute's office staff are necessarily limited to the immediate operation of the Observatory. Visitors should communicate their travel and observing plans to the IfA office in Hilo at least 3 weeks before their observing run, so that bookings can be made at Hale Pohaku and arrangements made for vehicle pick-up at the Hilo airport. Lists of pertinent names and addresses appear in Appendix A.

1.5.1 Transportation from Hilo to Hale Pohaku and Mauna Kea Observatory

Generally, observers on the 2.2-m telescope drive themselves in University 4-wheel drive vehicles which they pick up from and return to Hilo airport (see Fig. 1.2). This courtesy to visiting observers must be prearranged with the Telescope Superintendent. If no arrangement has been made, or no University vehicle is available for any reason, then transport is the responsibility of the observer. We usually require visiting observers on the 61-cm telescope to rent their own 4-wheel drive vehicles for the duration of their observing run. A list of agencies in Hilo that rent 4-wheel drive vehicles appears in Appendix A, and a number of agencies at the Hilo Airport rent ordinary standard-shift passenger cars (note that some of these agencies forbid driving on the Saddle Road).

University vehicles are parked in the airport parking lot. The vehicle you will use will most likely be a Ford Explorer. One of these is blue in color (UH7, automatic), another is green (UH2, automatic) and the third is red (UH5, manual). Observers who have a large amount of equipment may make a special request to use one of the two white Chevrolet Suburbans (UH3 and UH4). The vehicles cannot be parked in a consistent location, so you have to search the parking lot for the vehicle. They are most easily identified by stickers on their rear (e.g., UH2, UH5), their State of Hawaii license plates, and the University logo on the side.

The mid-level accommodation facility at Hale Pohaku is reached by a 90 minute drive over substandard roads (see Fig. 1.3). The first 45 km (28 mile) stretch, on State Highway 200 (Saddle Road) from Hilo to the turnoff (Humuula Sheep Station) is on a paved road, but with about one quarter of the asphalt surface in bad condition. Frequent curves and dips on this road restrict visibility, and drivers should be particularly wary of oncoming traffic; there is frequent heavy rain and fog which both makes the road slippery and restricts visibility. The most significant hazards are speeding and inattention at the wheel; observers should arrange their schedule to ensure they are well rested, and have ample time to make this journey. The route from the airport to the Saddle Road is shown in Figure 1.2. The turnoff from the Saddle Road to the access road to Mauna Kea is on the right-hand side, just before the 28 mile marker (there is no sign marking this turnoff as the road to Mauna Kea). The turnoff is opposite a small hill on the left which sticks out of the lava, and is also opposite a hunters' checking station.

The connection to Hale Pohaku from Highway 200 is by a 10 km (6 mile) paved road (see Figs. 1.3 and 1.4), which passes through open grazing land, and drivers should beware of stock wandering on the road. Although very steep in parts, this road can be negotiated by a standard shift automobile. Observers should check into the mid-level residence facility at Hale Pohaku before proceeding to the summit. More information about checking into Hale Pohaku may be found in Appendix C.

The 13.7 km (8.5 mile) road from Hale Pohaku to the summit should be driven only in 4-wheel drive vehicles. The road is rough in some places, and is always dusty. A 25 mph speed limit applies on this road. If dust masks are desired,

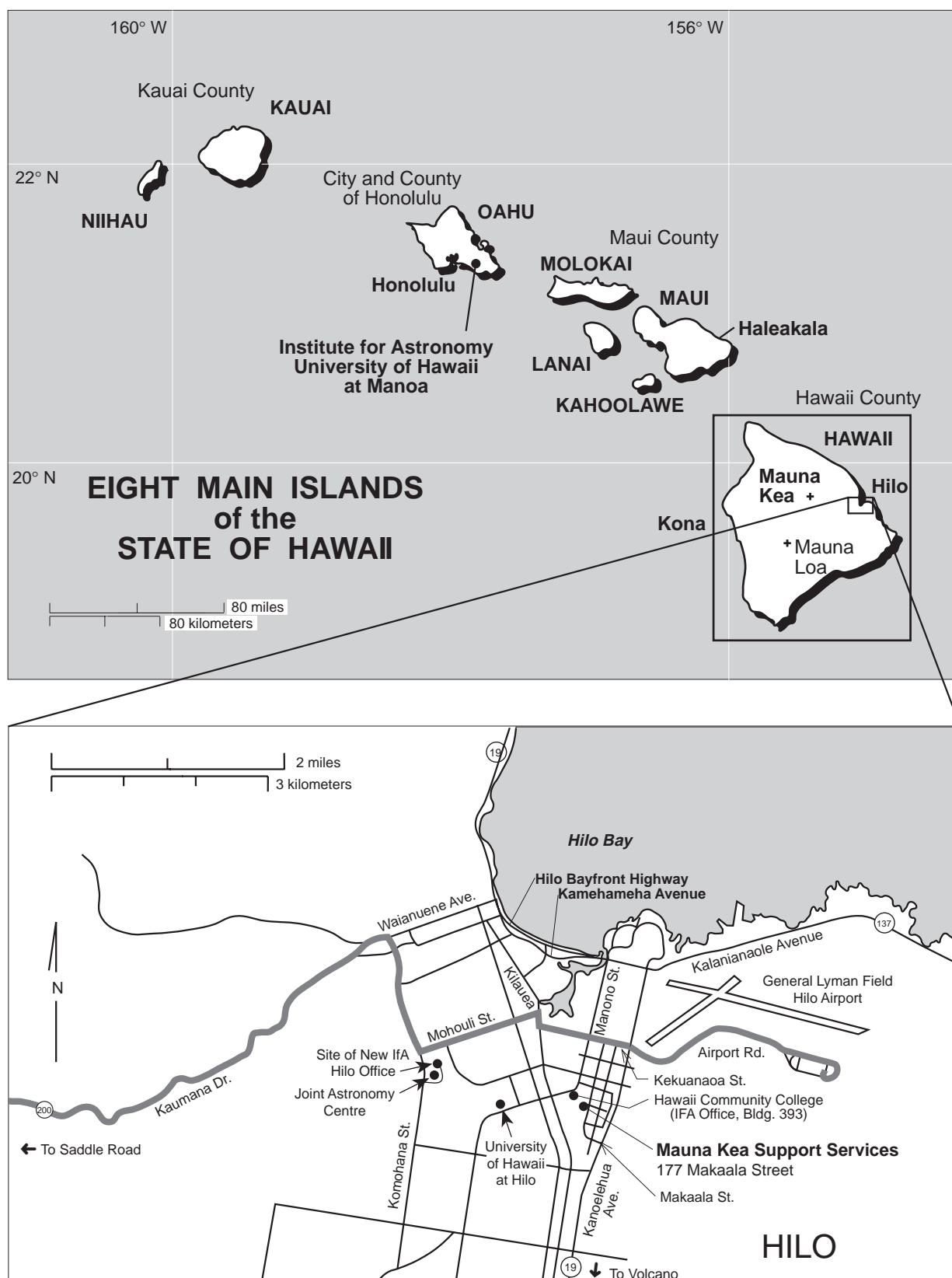


Figure 1.2: Eight main islands of the State of Hawaii, and the City of Hilo

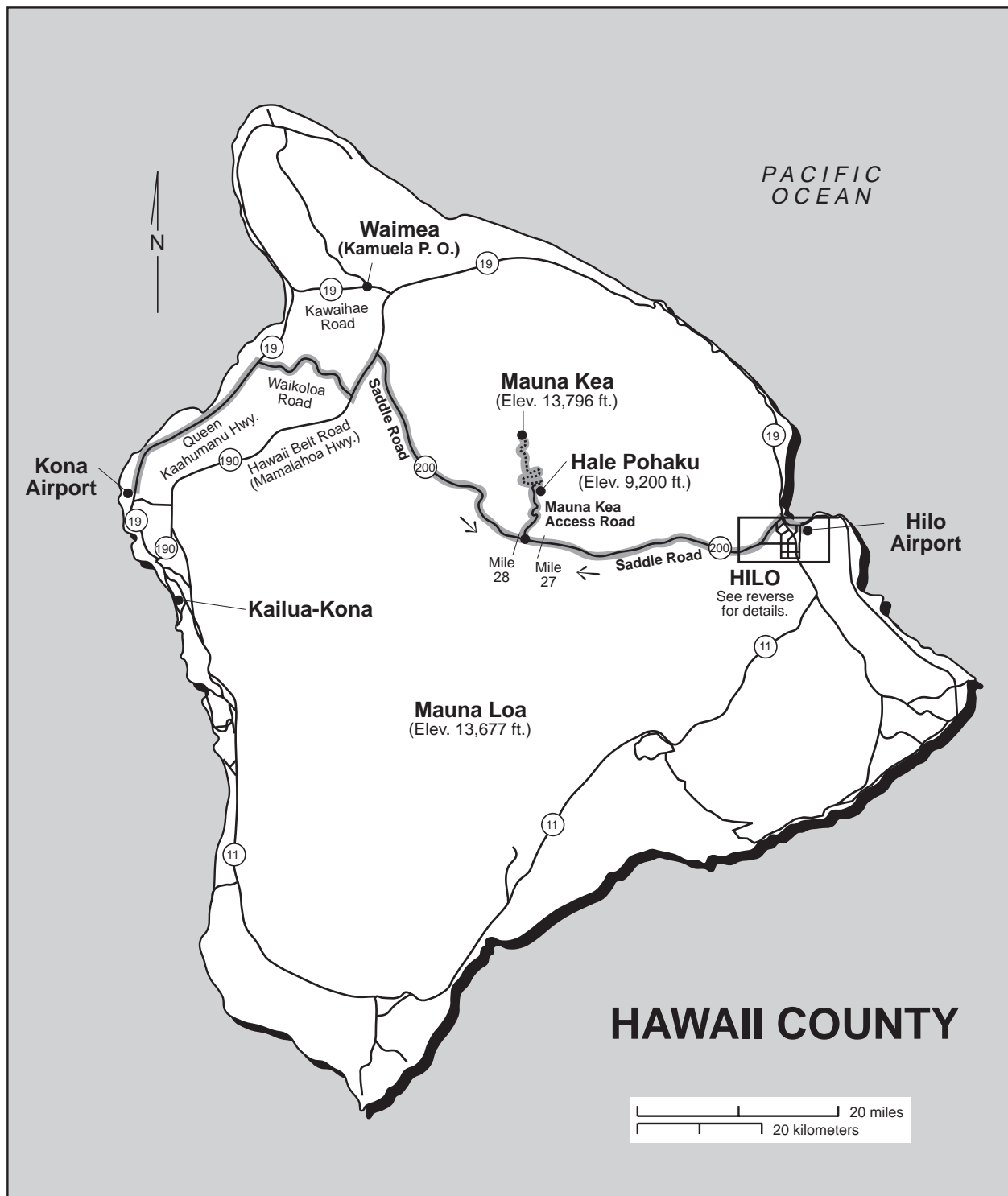


Figure 1.3: Road maps of the island of Hawaii, and access routes to Mauna Kea

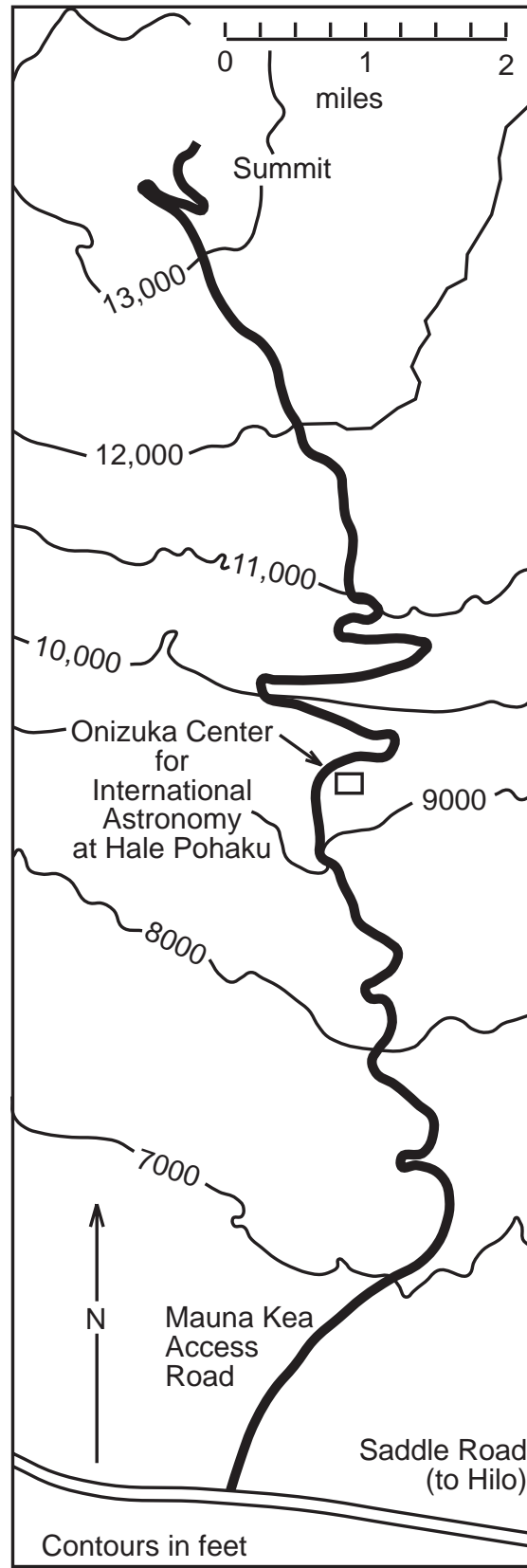


Figure 1.4: Map of Mauna Kea Access Road from the Saddle Road to the summit

they should be provided by the visiting observer. A map of the summit area is shown in Figure 1.5.

When you drive down to the airport after your observing run, be sure that there is enough gasoline in the tank for the next observer to drive back to Hale Pohaku. We recommend filling the tank before leaving Hale Pohaku if the tank is less than half full. At the airport, try to park as close to the terminal building as possible, in a location that will be easy for the next observer to find.

Visiting observers can occasionally obtain transportation to and from Hale Pohaku with the day crew, if it coincides with their regular weekday morning and afternoon schedule. Visiting observers will generally find it advantageous to be independent of the travel schedules of UH personnel.

Use of gasoline at Hale Pohaku will be billed separately at the end of the observing run, using the information provided on the gas log sheet at Hale Pohaku.

1.6 Accommodation—The Mid-level Facility, Hale Pohaku

Located at 2,835 m (9,300 ft) altitude, about midway between the turn-off from State Highway 20 and the summit of Mauna Kea, is the mid-level living facility, Hale Pohaku (Hawaiian for *Stone House*). This facility was named the “Onizuka Center for International Astronomy” (OCIA), after Ellison Onizuka, the Hawaiian born astronaut who was killed in 1986 when the Space Shuttle *Challenger* exploded. OCIA is run by Mauna Kea Support Services (MKSS), and provides accommodation for about 72 astronomers in single rooms with private bathrooms, and all meals including a night snack if desired. Details of the facilities available and charges are given in Appendices C and G. No toilet articles, cigarettes, stationery, postage stamps, etc. are available at Hale Pohaku, however—please bring a sufficient supply with you.

1.6.1 Telephone Service

Hale Pohaku and the telescopes now have reliable microwave-linked telephone services. We expect that all these phone lines will be moved to fiber optic cable later in 1997. The telephones at the 2.2-meter telescope and in the 2.2-meter telescope office at Hale Pohaku (and the IRTF) are connected to the state’s Hawaiian Advanced Telephone System (HATS). This system allows interisland calls to be placed toll-free using the state’s digital microwave system. To access this system, you must dial “8” first instead of the dialing “9” for an external line. To call a number at the IfA in Manoa, you therefore dial 8-1-808-956-xxxx. For local, interstate, or international calls you must dial “9.” To call another phone that is also on the HATS system, you simply dial the last 5 digits of the number. For example, to call the 2.2-meter telescope from the UH office at HP, dial 4-4200.

At Hale Pohaku, all toll calls are restricted. However, you can still make interisland calls using the HATS system by dialing “8” first. Observers are encouraged to use a credit card for interstate and international long distance calls. Calls to toll-free numbers are not restricted—dial 9-1-800 and the number. Interstate and international calls can be made from the summit at the 2.2-m and 0.6-m telescopes. Any long-distance calls dialed with “9” as the prefix must be logged at the telescope, and will be billed back to the originator of the call. There is no need to log any interisland calls made using the “8” prefix.

1.6.2 Mail Service

There is no regular mail service to or from Hale Pohaku. Long-term visitors may receive mail brought from the Hilo office by the Day Crew. Mail should be addressed to the individual addressee, in care of the UH Telescope Superintendent at the Hilo office address (see Appendix A).

1.6.3 Library

A small library of astronomical books, journals and photographic reference materials is located at Hale Pohaku. The principal holdings are:

- *Annual Reviews of Astronomy and Astrophysics* (all volumes)
- *Applied Optics* (Vol. 10, No. 1 [1971] to present)
- *Astronomical Journal* (Vol. 67, No. 1 [1962] to present)
- *Astronomy* (all volumes)

Figure 1.5: Mauna Kea Observatory site map

- *Astronomy and Astrophysics* (all volumes)
- *Astronomy and Astrophysics Supplement* (all volumes)
- *Astrophysical Journal* (Vol. 105 [1947] to present)
- *Bulletin of the American Astronomical Society* (all volumes)
- *Icarus* (Vol. 8, No. 1 [1968] to present)
- *Publications of the Astronomical Society of the Pacific* (Vol. 76 No. 448 [1964] to present)
- *Science* (Vol. 175, No. 4017 [1974] to present)
- *Scientific American* (Vol. 222, No. 1 [1970] to present)
- *Sky and Telescope* (Vol. 33, No. 1 [1967] to present)
- *Henry Draper Catalog, Smithsonian Astrophysical Observatory Star Catalog and Charts, Vehrenberg's Stern Atlas (Parts I, II, and III), Atlas Coeli 1950.0, and other miscellaneous reference publications.*
- the *Palomar Sky Survey prints* (plus southern extension)
- the *ESO/SERC Southern Sky Survey* (film copy)
- the new *Palomar Sky Survey* (film copy).

Since there is no resident librarian at Hale Pohaku, books and papers cannot be loaned out and must remain in the library at all times. A photocopying machine is available.

A workstation is also available in the library, for access to on-line catalogs.

Chapter 2

VISITING OBSERVER EQUIPMENT

2.1 Packing Goods for Shipping

Observers and their equipment must be prepared to endure a rather severe shaking each time they travel from Hilo to the summit. The consequences of the rough road are normally much more serious for delicate equipment than for personnel. Equipment sensitive to dust should be wrapped and sealed in plastic bags inside the shipping crates. Delicate components should be packed in small boxes and hand carried from Hilo to the summit. Normal electronic and mechanical components less sensitive to shock will usually survive the trip to the summit intact, but should be especially well packed—better than one would normally pack for transportation by a commercial shipper.

2.2 Transport

If equipment is in quantities small enough to fit into a half-ton truck, Observatory personnel can normally transport it to the summit, but usually at least one day after it arrives at the Hilo airport. Visiting observers requesting transport of their equipment should time its arrival in Hilo to precede their need for it at the summit by 4 to 5 days. Crates should have dimensions no larger than 1.2 m (4 ft) wide and 2.4 m (8 ft) long; height is unrestricted within reason. For ease of handling, crates should weigh no more than 100 kg (220 lb). Visiting observers who have large amounts of equipment to transport must arrange their own transportation and arrange for payment directly to the trucking company.

Shipment of scientific equipment and requests for its transport to the summit must be coordinated with the UH Telescope Superintendent. All equipment shipped Air Freight, which has originated from within the United States should be shipped directly to Hilo on an airline having a freight office in Hilo (see Appendix A for names of airlines). This will ensure that the freight does not get lost in Honolulu and that freight charges are paid all the way to Hilo on the Big Island of Hawaii, rather than only to Honolulu on the Island of Oahu.

Equipment originating from outside the United States, should be shipped to Hilo via Honolulu for Customs clearance (see the section below on Customs Regulations), with passage paid through to the final destination, Hilo.

2.3 Access to Domes

Large pieces of equipment can enter the 2.2-m telescope building through a freight door 3.35 m (11 ft) wide and 3.28 m (10 ft 9 in) tall; a 3600 kg (8000 lb) freight elevator connects the first and second floors with the observing floor. The elevator dimensions are 2.1 m (6 ft 11 in) high, 2.59 m (8 ft 6 in) wide, and 2.64 m (8 ft 8 in) deep. Mounted at the highest point in the dome is a 20 ton crane for moving heavy pieces of equipment into the dome from outside, and to any location on the observing floor. This crane is also used for moving equipment on to the Cassegrain observing platform when necessary. Visiting observers planning to use an electronics rack on the 2.2-m Cassegrain platform should provide eyes for attaching a cable from the crane. The Cassegrain platform at its lowest position is about 50 cm (20 in) above the concrete floor of the observing room. Electronic equipment can be mounted in the standard 19-inch racks attached to the Cassegrain rotator.

Visiting observers bringing equipment weighing more than 50 kg (110 lb) are strongly urged to mount it on a pallet for handling with a forklift. There is no crane or other lifting device at the 61-cm telescope.

2.4 Customs Regulations for Observers from Foreign Countries

All equipment and materials originating outside the United States and destined for Hawaii must be cleared through Customs in Honolulu, where fully staffed Customs offices are located. Since the Customs procedure is complex and best handled by a licensed Customs broker, the Institute has arranged for a local (Honolulu) Customs brokerage firm (Skelton-Kohara) to serve visiting observers (see Appendix A for address), although other brokers are available. It is extremely important that the visiting observer contact the Customs broker directly to engage his services and to obtain instructions. Some particularly important guidelines are indicated below.

2.4.1 Equipment Eligible for Customs Duty Exemption

Scientific equipment that will be returned to the country of origin within one year of entry may be entered bonded and duty-free, provided it is cleared through Customs in Honolulu on entry and exit. The most important thing to keep in mind concerning such equipment is that it must be identifiable by the Customs agent when it enters Honolulu, and it must be reidentified when it goes out, in order to prove that the equipment has indeed left the country. In this regard, it is advisable to do the following when arranging shipment:

1. Crate those items for which duty exemption is requested.
2. For each crate, prepare a list showing the quantity, description (in English), and value of each piece of equipment in the crate. Number each crate, indicating that number on the appropriate list of contents.
3. Have the shipper prepare a cargo manifest (in English) so that it corresponds to the crate numbers and the content lists you have prepared.
4. Be sure that any airbills, waybills, etc. contain the following annotation: "NOTIFY INSTITUTE FOR ASTRONOMY, HILO, HAWAII [(808) 974-4205] AND (NAME, ADDRESS, AND TELEPHONE NUMBER OF YOUR CUSTOMS BROKER IN HAWAII)".
5. Airmail, without delay, copies of cargo manifests, carriers certificates, airbills/waybills, and crate content lists to both the Hilo Office and to your Customs broker.
6. Address and label your crates to include the following information:

(1) Your return address;
 (2) Ultimate Destination:
 Institute for Astronomy,
 c/o (UH Telescope Superintendent's name)
 for (your name),
 Institute for Astronomy,
 1175 Manono Street, Building 393,
 Hilo, Hawaii 96720, U.S.A.,
 telephone (808) 974-4205;
 (3) By way of;
 name, address, and telephone
 number of your customs broker;

(4) This annotation:
 "SCIENTIFIC EQUIPMENT TO BE RETURNED
 TO COUNTRY OF ORIGIN WITHIN ONE YEAR OF ENTRY".

7. Arrange to be present in Honolulu at the import and export proceedings.

2.4.2 Equipment to be Consumed or to Remain in the United States

Equipment of this nature should be declared and listed separately from that which will be returned to the country of origin within one year. The same procedure as that indicated above should be followed, with the exception that the notation shown in item (4) of the address instructions above should read: "TO BE CONSUMED" (or "TO REMAIN IN THE UNITED STATES").

2.4.3 Returning Equipment to Country of Origin

Before you leave Hilo, recreate your equipment in the same groupings in which it entered. Number the crates to coincide with the contents lists under which they entered. Address the crate showing:

Ultimate Destination:
(address, etc.).
By way of:
(name and address of your
Honolulu Customs broker).

This will assure that the freight will go through Customs in Honolulu. Notify your Customs broker that you are ready to ship the equipment. Please do not leave Hawaii until the shipment has been cleared by Customs or until your broker has indicated that all is in order.

2.4.4 Additional Information

Additional information concerning Customs regulations or procedures can be obtained from your Customs broker, or from the District Director of Customs (see Appendix A for address).

It is the responsibility of the visiting observer to document any change in the number of items being exported from the number of items being imported. To simplify matters, we suggest that you use the same crates in both instances.

Shipments to UH telescopes at MKO should be addressed as follows:

Institute for Astronomy
c/o (UH Telescope Superintendent's name)
1175 Manono St, Building 393,
Hilo, Hawaii USA 96720
Telephone (808) 974-4205

By way of:
Skelton-Kohara & Co., Customs Brokerage
736 South St, Room 201
Honolulu, Hawaii USA 96813
Telephone: (808) 524-2663
Fax: (808) 533-7097

Chapter 3

WEATHER AND SITE QUALITIES

3.1 Weather

Minimum temperatures at the summit are generally at or below freezing, but rarely go lower than -10°C (14°F) during the winter. In the summer, they usually range around freezing. Daytime temperatures are normally about 10°C (50°F). Data on mean temperatures and wind speeds are shown in Figure 3.1.

Weather conditions can change *very* rapidly—you should always be prepared to leave the summit with little or no notice. Figure 3.2 shows wind velocity measurements for the year of 1993. Notice that several times each year, the wind velocity exceeds hurricane force, with the peak velocity for 1993 being 130 mph. You *must not* attempt to go to the summit in these weather conditions. Always check the road conditions with the staff at Hale Pohaku if there is any question about the condition of the road. You may also call (808) 969-3218 for recorded information about road and weather conditions. The current UKIRT weather is available at the URL <http://www.jach.hawaii.edu/cgi-bin/getwx.pl/UKIRT>. When the conditions are bad or marginal, a notice board is usually positioned near the Hale Pohaku entrance—please read it.

Figure 3.3 shows temperature measurements for the year of 1993. The plot shows the diurnal temperature variation, as well as the seasonal variation.

3.2 Cold-weather Gear

Clothing adequate to withstand sustained cold temperatures is essential for observations at the unheated 61-cm dome, for 2.2-m observers who expect to spend a significant time in the dome or on the Cassegrain platform, and for all observers moving between vehicles and domes. Cold-weather clothing can be borrowed from MKSS at Hale Pohaku, for a small rental fee to cover cleaning costs.

As mentioned previously, nighttime temperatures seldom drop very low, but high winds and freezing rain are common during the winter months and are possible any time. Several rooms in the 2.2-m building are heated, including a working area where instruments can be assembled. The 61-cm dome is not heated.

3.3 Site Quality

A description of conditions on Mauna Kea during the construction of the Observatory can be found in *Sky and Telescope*, **36**, September 1968; astronomical characteristics of the site are described in *PASP*, **85**, June 1973.

Typical zenith dark sky brightness values for Mauna Kea are $B = 22.4$, $V = 21.1$, $R_C = 20.3$, $J = 16$, $H = 14.5$, $K' = 14.0$, and $K = 13.5$ mag arcsec $^{-2}$.

A good summary of the sky brightness at optical wavelengths, the transmission at infrared wavelengths and extinction is contained in the CFHT User manual, and users are referred to this for additional data.

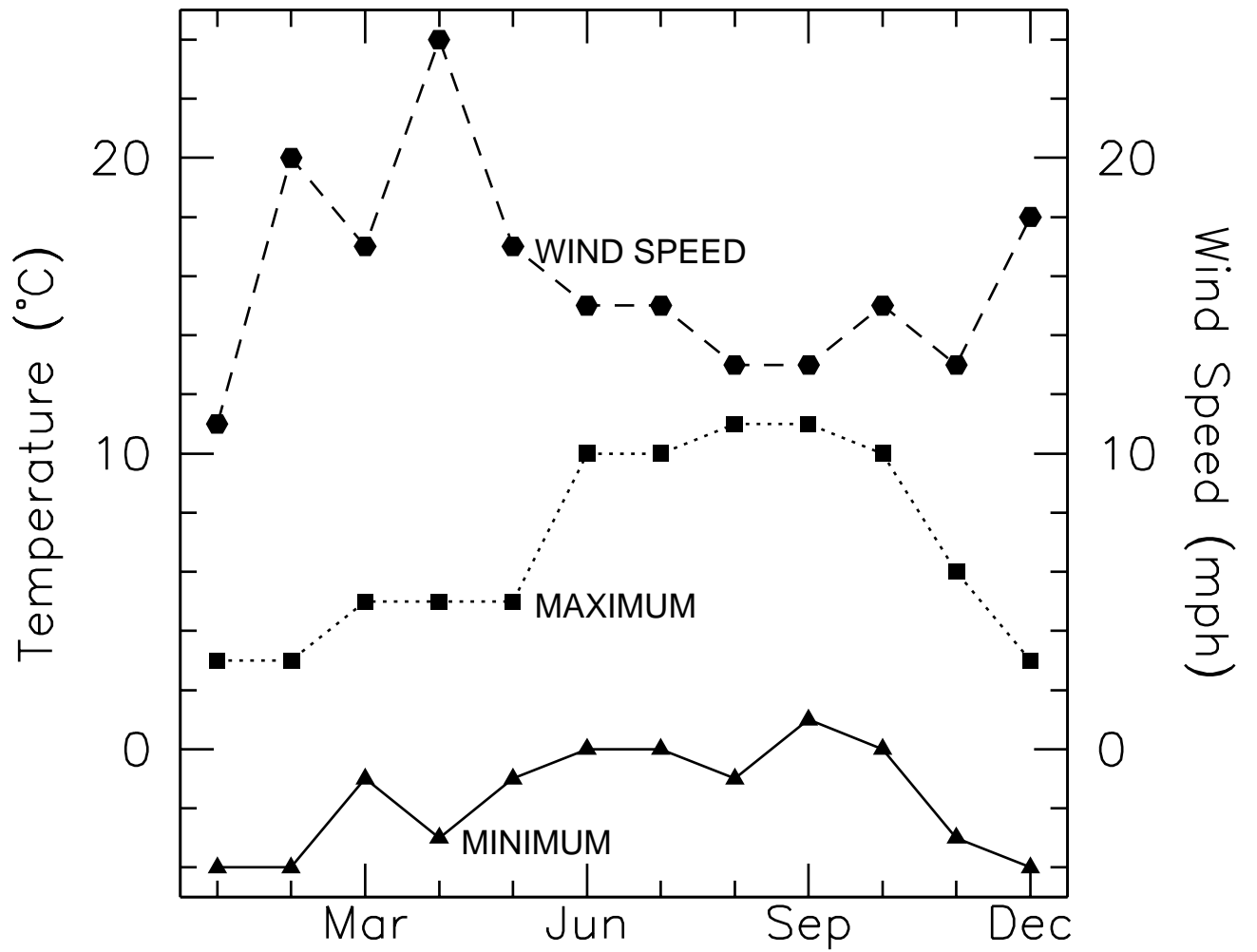


Figure 3.1: Mean temperatures and wind velocity at Mauna Kea, 1965–1969

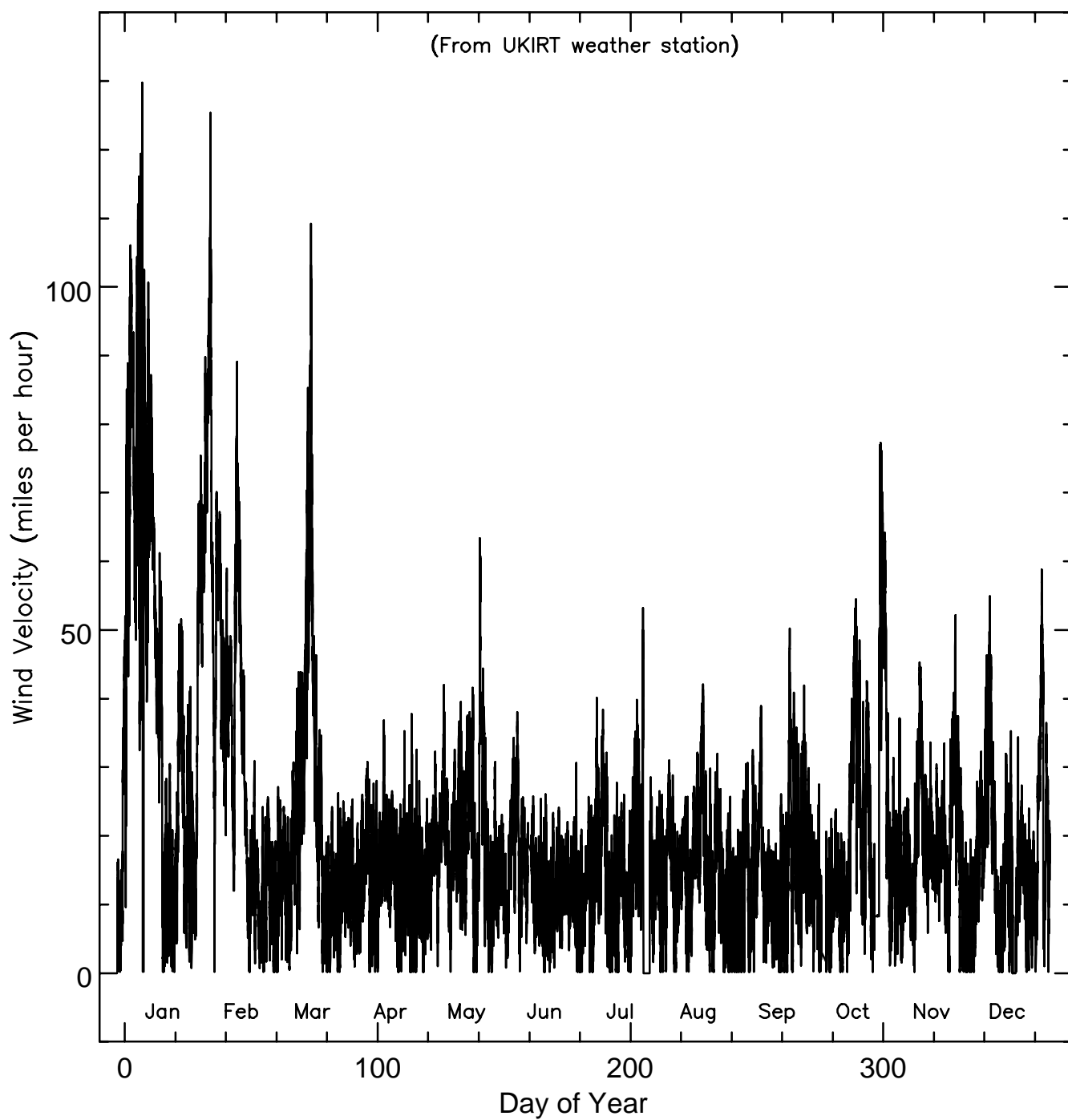


Figure 3.2: Wind velocity at Mauna Kea Observatories—1993

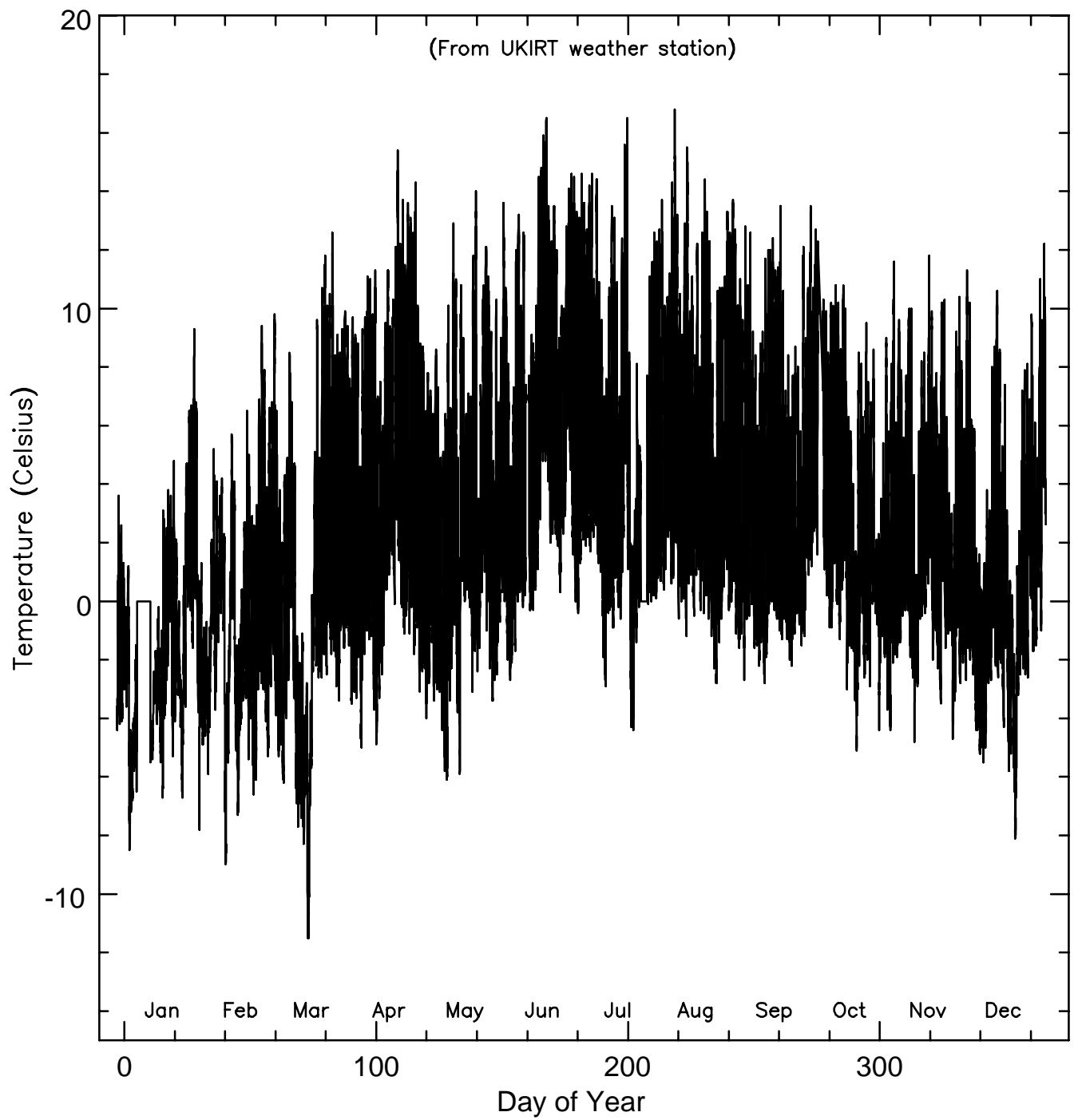


Figure 3.3: Temperatures at Mauna Kea Observatories—1993

Chapter 4

SUMMIT FACILITIES AT THE UH TELESCOPES

4.1 Computers

The computer facilities are being continually upgraded to meet the changing needs of observers. The 2.2-m telescope is connected via an FDDI fiber-optic network to other telescopes on the summit and to Hale Pohaku, and from there, via a T-1 microwave link, to Manoa, and the internet. There are two ethernets in the 2.2-m telescope building. One ethernet connects all computers associated with the 2.2-m telescope, and another connects all computers associated with the 61-cm telescope (a fiber-optic cable connects the 61-cm telescope to the 2.2-m telescope). Thick and twisted pair ethernets are used at the 2.2-m telescope. Thin ethernet is used at the 61-cm telescope. Both ethernets have restricted access—communication is only allowed to a small number of trusted external sub-networks.

Our principal disk storage area is located at Hale Pohaku. Observers are expected to transfer their data daily to Hale Pohaku to be written to tape. In those cases where a small detector is used, direct transfer of data to an external computer is practical, but we nevertheless strongly recommend that a tape is written as a backup. We presently use exabyte 8mm tapes for tape archiving of data.

The most commonly used computers presently in use (and their functions) are listed below:

- A DEC LSI-11/23 operating under FORTH. This dedicated machine is operated by the Telescope Operator (TO) for control of the 2.2-m telescope.
- An Dell 386/20 PC running MS/DOS which controls guiding at the coudé focus. It can also provide guide signals for visitor instruments with their own guide camera (a video signal is required).
- A Sun SPARCstation 2 (*tycho*) with color monitor, 0.5 and 1.0 Gbyte disks, two CD-ROM drives, 48 Mbyte of memory, and a 300 dpi laser printer. The operating system is Unix (SunOS 4.1.4). This workstation interfaces directly with the Telescope Control System; the workstation is normally used by the Telescope Operator, who controls the telescope from a window on *tycho*'s monitor. It also serves as a backup in case of failure of the other Sun at the summit. The HST guide star catalog is normally kept on-line in the CD-ROM drives, and is frequently used to rapidly find offset guide stars. Observer access is normally limited to guide star selection.
- A Sun SPARCstation 20/71 (*wekiu*) with color monitor, 1.0 and 4.0 Gbyte disk drives, and 96 Mbyte of memory. The operating system is Unix (SunOS 4.1.4), and windowing systems are X11R6 and OpenWindows. Standard analysis packages such as IRAF and IDL are available. This workstation is normally used by the observer at the 2.2-m telescope. QUIRC and KSPEC and some of the CCDs are run directly from it. It is also used for quick-look analysis of data, as well as to store the night's data from the instrument being used.
- A Sun SPARCstation 2 (*halley*) with color monitor, 0.4, 4.0, and 1.5 Gbyte disks, 64 Mbyte of memory, and exabyte tape drive. The operating system is Unix (SunOS 4.1.4), windowing systems are X11R6 and OpenWindows, and standard analysis packages include IRAF and IDL; it is setup in a similar manner to the workstations at the IfA. This workstation is normally used by the observer at the 61-cm telescope. It is normally located in the 2.2-m telescope computer room. When QUIRC is used at the 61-cm telescope, *halley* is used to control it; QUIRC can be run remotely over the fiber-optic cable which connects the 61-cm telescope with the 2.2-m telescope. When *halley* is not in use at the 61-cm telescope, it may be used by the observer at the 2.2-meter telescope.

- Two NeXTstations (*anaconda* and *cobra*), each with 32 Mbyte of memory, and an external disk drive, for control and data acquisition from CCD detectors.
- A NeXTstation *viper* for control of the offset guider and for tip-tilt guiding.
- A Sun SPARCstation 10/41 *baade*, located in the UH computer room at Hale Pohaku, with color monitor, 0.4, 1.6, and 3×2.0 Gbyte disk drives, CD-ROM drive, exabyte tape drive, and 96 Mbyte of memory. This computer is our most powerful workstation at Hale Pohaku, and is setup in a similar manner to *wekiu* and *halley*. It is used as the principal data storage and data archiving computer, and for detailed examination of data during the daytime.
- A Sun SPARCstation IPX *kepler*, located in the 2.2-m telescope office at Hale Pohaku, with color monitor, 0.4 and 1.0 Gbyte disk drive, and 48 Mbyte of memory. This is intended to be used principally as an X-terminal to *baade*, which has most of the disk drives and peripherals.

The only form of data archiving presently supported is exabyte tapes. These tape drives use 8mm video cassettes, and a 120 min tape can hold approximately 2.3 Gbyte of data. Tapes are not supplied to observers—observers should bring an adequate supply of tapes with them. We recommend the use of data grade 8mm tapes. Their cost is in the range \$8–10 each, depending on brand, quantity purchased, and source. Examples of tapes which we know work well are Sony and Exabyte data cartridges. Recent changes in the manufacturing process for the Sony MP tape (which we previously recommended) have caused unacceptable failure rates with these cheaper tapes, and we recommend that they are not used.

We strongly recommend that observers make at least two exabyte data tapes of all data, in case of problems with a tape. Data may be written onto more durable, and more reliable CD-ROM media in Manoa after the observing run. CD recordable disks presently cost approximately \$8 each, and hold approximately 650 Mb on a 74 minute disk.

4.2 Mechanical Shop

A small mechanical shop in the 2.2-m building contains a band saw, vice, drill press, grinder, lathe, and an assortment of hand tools. This equipment is not suitable for instrument fabrication and is for emergency repairs only. Visiting observers should bring their own tools.

4.3 Electronics Shop

A small electronics shop in the 2.2-m building is used for servicing the telescopes, instruments and control equipment, and contains a modest assortment of wire, miscellaneous electronic components, soldering irons, and simple test equipment. Visiting observers should not rely on this facility, except to provide possible emergency back-up if they experience simple difficulties with their own equipment. Visiting observers should bring their own supply of spare parts and test equipment.

4.4 CCD/IR Dewar Lab

A small, 200 ft², unheated area with work bench and cabinet space is available on the ground floor of the 2.2-m building. A turbo pump is located in these room, along with a modest selection of ordinary hand tools, which are available for repair, adjustment, and testing of instruments.

4.5 Power at the Summit

Electrical power at the summit is now provided by the Hawaiian Electric Company (HELCO) transmission grid. Voltages available are 480 V, 277 V, 208 V, and 120 V in a three-phase, four-wire, 60 Hz distribution system. Regulated 110 V from wall sockets is also available. Two small Uninterruptible Power Supplies (UPS) provide power to the 2.2-m telescope control computer, data acquisition and instrument control computers, and instruments, in the event of short power outages, and a small generator provides power for closing the 2.2-m telescope dome in the event of a complete outage.

4.6 Living Facilities in the 2.2-m Building

A heated room in the 2.2-m building is provided with comfortable furniture, a cot and a kitchenette. This facility is for use by astronomers and assistants for short rest periods during the day or night. A stock of several days' food is maintained at the summit—this is *for emergency use only*, in case observers or staff are trapped at the summit by sudden, severe weather (heavy snow can close the road for many days). The emergency food is stored in a storage room adjacent to the day room, on the ground floor of the 2.2-m telescope building.

4.7 Loaned Facilities

On special occasions, certain instruments or apparatus may be loaned to visiting observers who have experienced difficulty with their own equipment. Visitors should not, however, rely on the availability of any apparatus on loan unless prior explicit arrangements have been made in writing with the Director. This applies, for example, to such items as vacuum pumps, oscilloscopes, amplifiers, cryogenic transfer tubes, etc.

Chapter 5

SUPPLIES

5.1 Dry Ice

Solid CO₂ snow can be made at the Observatory in small quantities (several ounces) by rapid expansion from bottles of compressed gas; bottled CO₂ is normally available for modest demands. Larger quantities of dry ice can be obtained in Hilo, but this requires advance notice of several days. For quantities over 2 kg, requirements should be indicated on the “Visiting Observer Information Sheet”.

5.2 Liquid Nitrogen and Liquid Helium

The purchase and handling of these cryogenics is supervised from Hilo (see Appendices for person to contact). Visiting observers requiring modest amounts of LN₂ (25–160 liters) for a single observing run are requested to coordinate their needs through the UH Telescope Superintendent on the “Visiting Observer Information Sheet”. There are presently no facility instruments which use liquid helium; liquid helium is now only rarely used, and only with visitor instruments. Requests for LHe must reach Hilo by telephone or in writing a minimum of 4 weeks before the day they are needed.

It is most economical to purchase LHe in 30, 60 or 100 liter dewars, and the LN₂ in 160 liter dewars owned by UH. Visiting observers using cryogenics will be billed following their observing run for the amounts they ordered or used, whichever is greater. Liquid nitrogen is produced in Honolulu and shipped by barge to Hilo, where it is transported to the summit by UH personnel. On reaching the summit, a 160 liter dewar shipped full from Honolulu normally contains 150 liters. LHe is air shipped from Honolulu by Gaspro and is distributed by Gaspro, Inc., in Hilo. Users should consider the loss factor when estimating their needs. The current approximate costs of LN₂ and LHe delivered to the summit are listed in Appendix G.

The freight address of the Institute for Astronomy in Hilo (listed in Appendix A) should be used for shipments of cryogenics ordered by individuals.

5.3 Pumping and Transfer Tube Information

The rubber hose used for pumping liquid helium in the infrared detector dewars is about 2.5 cm (1 in) in inside diameter and 4.9 m (16 ft) in length. The transfer tube diameter is 6.4 mm (0.25 in) on the delivery side, with a smaller tube diameter of 3.3 mm (0.13 in), and length of 3.8 cm (1.5 in) on the end. The mechanical pump is a Welch pump, with a capacity capable of pumping most LHe dewars. A turbo pump is available for pumping the vacuum casing of dewars.

Chapter 6

TELESCOPES

Visitors requiring specific information about the optical or mechanical configuration of the telescopes should communicate with the Support Scientists of the UH Telescope Superintendent in Hilo.

6.1 61-cm (24-inch) Telescope

This telescope, made by Boller and Chivens and furnished to the University by the US Air Force, is located in a small dome 150 m southwest of the 2.2-m dome, below UKIRT. It is used mainly for wide-field imaging and photometry. The Cassegrain focal lengths are 9,240 mm (f/15.2) and 36,500 mm (f/60), providing scales of 22.3 and 5.65 arcsec mm⁻¹. An f/35 chopping secondary is also available for infrared work. The telescope is used almost exclusively with the f/15.2 secondary mirror. No one presently at the University has any experience with the f/60 secondary mirror.

The telescope is capable of variable tracking rates in both Right Ascension and Declination. The telescope can be pointed manually, by reference to setting circles which are accurate to about 1 arcmin in each axis. A computerized control system (using a 486-PC) for this telescope has been installed, and is still undergoing testing. Since May 1996, we have been able to control this telescope remotely and robotically. Work is still underway to make this remote operation safer and more robust. Fiber-optic cables link this telescope to the 2.2-m telescope dome, providing a fiber ethernet connection, fibers for instrument control, and a fiber for a video camera to remotely view the status of the telescope.

This telescope is not generally available for use by visiting observers.

The layout of the instrument mounting flange of the 61-cm telescope is shown in Figure 6.1. An offset guider (with eyepiece), which has a mirror which can be moved on axis for object acquisition, is commonly mounted onto the telescope. Instruments such as QUIRC and the filter wheel/CCD normally mount onto this guider. The guider is 8 inches thick, meaning so most instruments mounted onto it have their focal planes close to the nominal focal plane, located 12 inches behind the instrument rotator.

A 25-cm telescope (Ritchey-Chrétien f/10) can be mounted on the counterweight side of the polar axis of the 61-cm telescope. This 25-cm telescope can only be used with the 1024×1024 near-infrared camera (QUIRC). The 25-cm telescope mounts on top of QUIRC, and QUIRC is mounted to the 61-cm telescope. The combination of 25-cm telescope and QUIRC is referred to as QUIST (QUick Infrared Survey Telescope). QUIST has a field of view of 29'×29' with pixels of 1.70". QUIST is still in experimental use, and we request that astronomers consult with support staff before submitting a proposal to use this instrument.

6.2 2.2-m (88-inch) Reflector

The fused silica primary has a diameter of 2.24 m (88.13 in), an unvignetted diameter of 2.22 m (87.5 in), an edge thickness of 291 mm (11.47 in), and weighs 2.17 tons (4780 lb). The hole in the center of the primary mirror has a diameter of 24.13 in (613 mm).

The nominal f/10.14 Cassegrain (Ritchey-Chrétien) focus has a focal length of 22.50 m (886 in), an unvignetted field of 46 arcmin, and a field image scale of 9.17 arcsec mm⁻¹ (109 μm arcsec⁻¹). Nominal (RC) focus is 313 mm (12.32 in) behind the mirror cell, or 100 mm below the bottom surface of the instrument adapter/offset guider used for most Cassegrain instrumentation (see Section 7.2). Maximum telescope focus range at f/10 is from the back of the mirror cell to 68.5 cm (27 in) behind it, but the focus range of the offset guider TV is presently only ±30 mm around the nominal

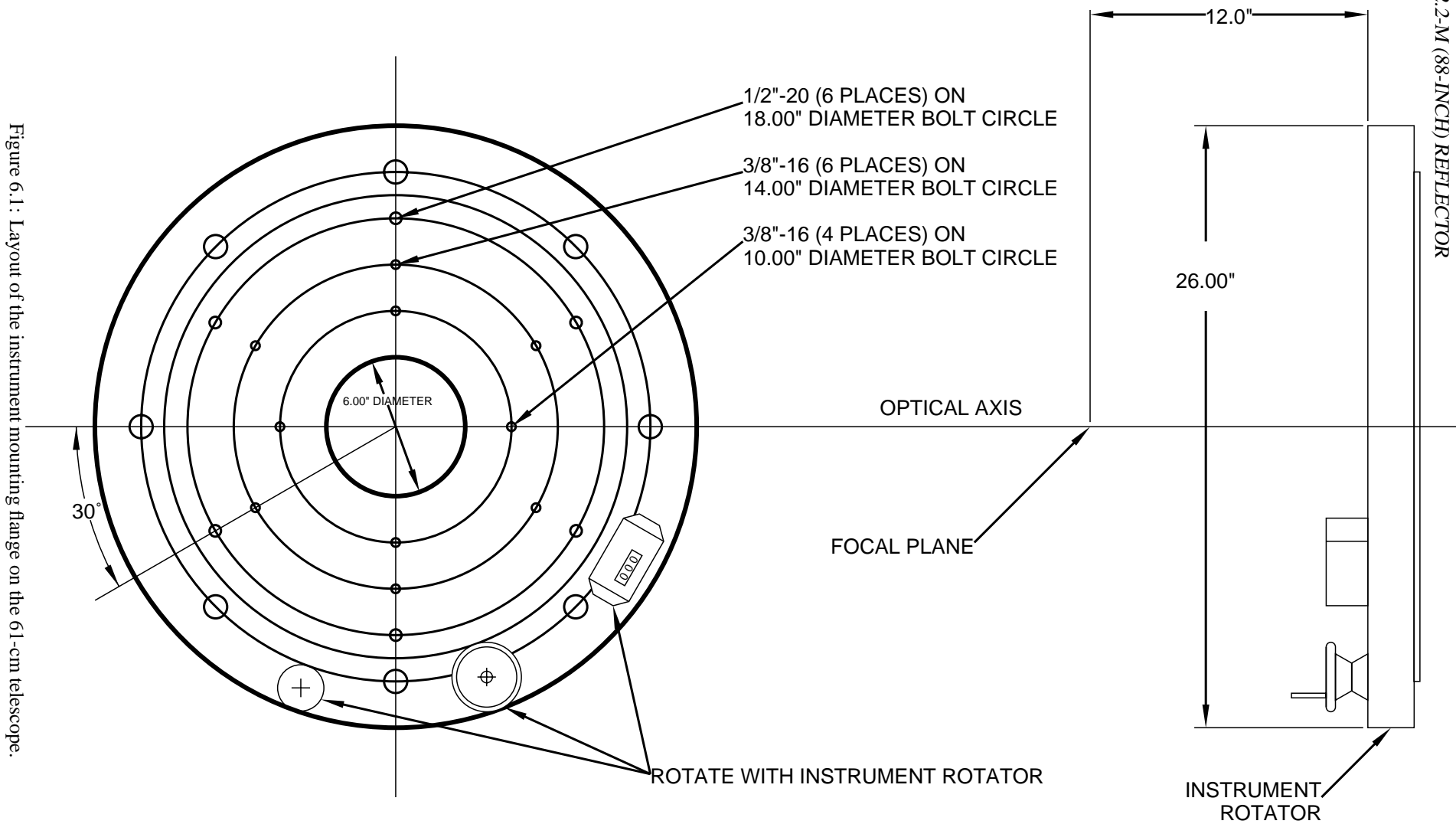


Figure 6.1: Layout of the instrument mounting flange on the 61-cm telescope.

Table 6.1: 2.2-m primary and secondary mirror dimensions and curvatures

	Primary	f/10	f/33.8	f/31
Diameter	2.239 m	0.660 m	0.610 m	0.211 m
Thickness	0.291 m	0.102 m	0.102 m	
Radius of curvature	12.3445 m	-4.19819 m	-3.32105 m	-1.2936 m
Conic constant	-1.0535	-3.604		-2.173

focal plane. The nominal separation between the primary and secondary mirrors is 183 in (4.65 m).

The 5 mirror f/33.8 coudé focus has a focal length of 75.20 m (2,961 in), a useful field of 3.5 arcmin, and an image scale of 2.7 arcsec mm⁻¹ (367 μ m arcsec⁻¹). The coudé focus is located in an enclosed slit room (see section 6.2.4). The Cassegrain and coudé optical trains can be interchanged in about 30 min during the night, if necessary, for special programs.

These two foci share the same focus drive which moves within the encoder range 91–17553. Each step (of 27 μ m) represents movement of the f/10 Cassegrain focal plane by 39 μ m (0.00154 in), or of the f/34 coudé focal plane by 426 μ m (0.0168 in), with increasing number indicating movement of the f/10 secondary *towards* the primary (and of the f/34 secondary *away* from the primary).

Focusing should normally be determined to 10 units (or better) to restrict focusing blur to less than 0.3 arcsec. With the CCD, focusing is usually done by taking a “focus plate” (a sequence of images at different focus settings. A video rate CCD readout is expected to be available soon, which will make it easier to focus the telescope on bright stars.

The Cassegrain f/31 secondary has been optimally figured to match the shape of the primary mirror, and has an enclosed energy of 80% within 0.2 arcsec. The secondary mirror is mounted to the spiders and top-end ring via a hexapod mount, which allows 6 degrees of freedom of movement, so that collimation, tilt, and focus adjustments can be made remotely. The mirror is attached to the hexapod mount via a piezo-electrically driven platform that is used for tip-tilt correction. The tip-tilt correction is easy to use and is available to all observers who use the f/31 secondary mirror.

A top-end change is required to use the f/31 secondary mirror. With this mirror, the telescope has a nominal focal length of 68.78 m (2707 in), producing an image scale of 3.00 arcsec mm⁻¹ (333 μ m arcsec⁻¹). Exact focal length depends upon exactly where the instrument focal plane is located relative to the mirror cell.

Basic specifications (where known) for the mirrors at the 2.2-meter telescope are listed in Table 6.1. Additional details, including figuring errors, may be found in Table 7.2.

There is no infrared chopping secondary mirror. The old f/35 chopping secondary has been replaced by the fixed f/31 secondary mirror, and is no longer available. Instruments which work in the thermal infrared (beyond 2.5 μ m) and require chopping therefore can no longer be used on the 2.2-m telescope. The InSb photometer and Ge Bolometer, which until 1990 were used with the chopping secondary mirror, have been decommissioned, and are not available.

The 2.2-m telescope also has two bent Cassegrain foci, which can be used with either the f/10 or the f/31 secondary mirrors, together with the coudé tertiary mirror (which is mounted in the sky baffle attached to the center of the primary, and rotates with the instrument rotator). The tertiary mirror can be moved in and out of the beam remotely, and reflects light to the coudé system at instrument rotator position 270°, to the south bent Cassegrain focus at rotator position 180°, and to the north bent Cassegrain focus at rotator position 0°. These additional foci are used for special purpose instrumentation, and are not available for visitors’ equipment.

Telescope track rates up to 99 arcsec s⁻¹ away from nominal are possible in either Right Ascension or Declination, and can be set to 0.0001 arcsec s⁻¹.

To facilitate balancing the telescope, visiting observers who mount their own equipment at the Cassegrain focus should know the weight of their instrument, including the weight of dry ice, cryogenics, hanging cables, and the position of the center of gravity. Observers who dismount equipment (such as dewars) during their run should supply a dummy balancing weight. Electronics to be mounted on the telescope should preferably be made to fit inside standard 19-inch racks.

The layout of the telescope and dome are illustrated in Figures 6.2 and 6.3, the layout of the 2.2-m Cassegrain instrument mounting flange is shown in Figure 6.4, and the layout of the 2.2-m bent Cassegrain instrument mounting flange is shown in Figure 6.5. Note that instruments are normally *not* mounted directly onto the Cassegrain mounting flange. Instead, they are mounted onto the offset guider, which is described in Section 7.2, and its bolt circle is described in Section 7.2.3. There is presently no ability to guide at the bent Cassegrain focus; this focus is not normally used.

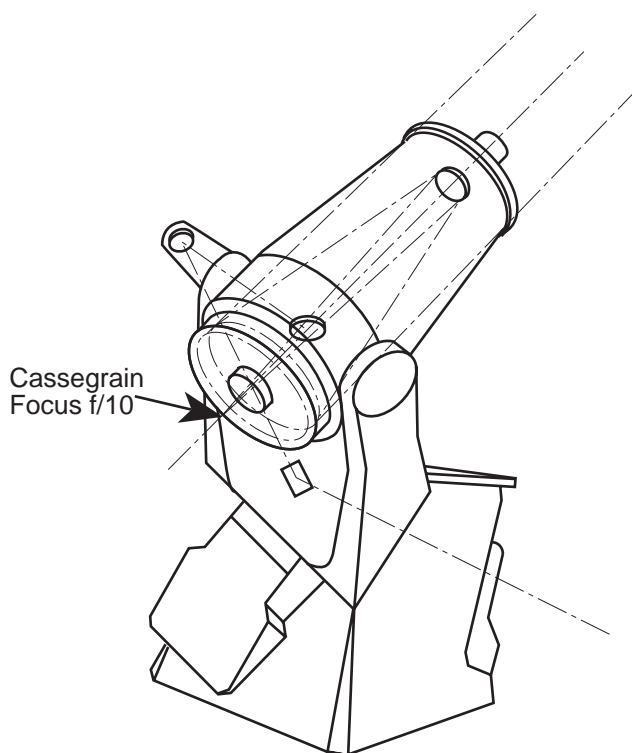


Figure 6.2: Optical configuration of the 2.2-m telescope

6.2.1 Telescope Control System

The 2.2-m telescope positioning, tracking and slewing are controlled by an LSI-11/23 computer programmed in FORTH. The computer itself is not part of any feedback loops, but merely sets hardware values according to requirements. The computer pointing model includes corrections for atmospheric refraction and telescope flexure. Pointing (slewing) is accurate to 10 arcsec RMS over the whole sky, with offsets up to a few arcmin accurate to 2 arcsec. Unguided tracking is generally good to several arcsec hr^{-1} , but the telescope is normally autoguided using the TV system. A facility for guiding at non-sidereal rates is now available for observations of solar-system objects.

Telescope position control operates via a conventional phase-lock loop using up/down counters to determine position error. When the telescope is tracking, the computer increments these counters, while incremental encoders on the telescope drives detect telescope motion and decrement the counters. Each count represents 0.05 arcsec on each drive axis, and an inner feedback loop operating at about 10 Hz sends signals to drive the telescope at a velocity proportional to the number of counts (position error). The gain is set high so that one or two counts will drive the telescope at normal track rates with negligible error. The desired track rate on both axes can be set and adjusted in real time by thumbwheel switches on the control panel, which the computer reads. The maximum track rates are within 99 arcsec s^{-1} of sidereal, for solar system objects, with resolution to 0.0001 arcsec s^{-1} . Slewing is achieved by applying a relatively large input directly to the velocity control loop.

Absolute position is also measured with incremental encoders with resolution of $\frac{1}{16}$ arcsec on both axes. These encoders and the TCS are energized through the Uninterruptible Power Supply so that positional information is maintained throughout short power outages. If the absolute position is lost, however, the system must be reinitialized by setting the telescope accurately to the zenith with two precision bubble levels, and loading the proper numbers into the counters.

Communication between instrument computers and the TCS is now in common use. This is achieved via a communication daemon, running on *tycho*. Commands and protocol are similar to the system at the IRTF. Further details can be obtained from support staff if required.

6.2.2 Cassegrain Observing Platform

A platform which can be raised and swiveled hydraulically provides access to instrumentation at the Cassegrain focus of the 2.2-m telescope. Permanently located on the platform is a mobile electronics rack which houses a panel for platform

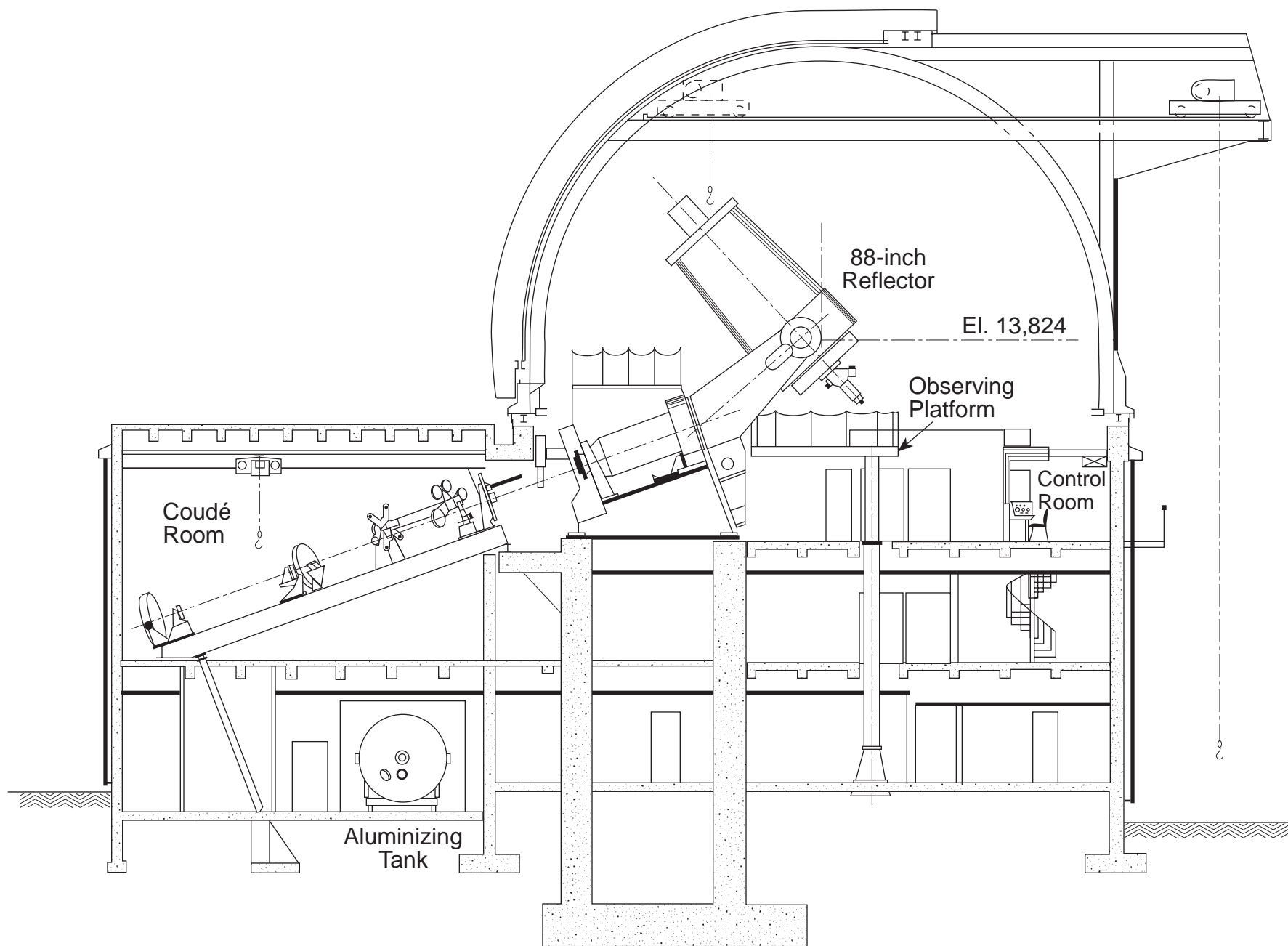


Figure 6.3: Layout of the 2.2-m telescope dome

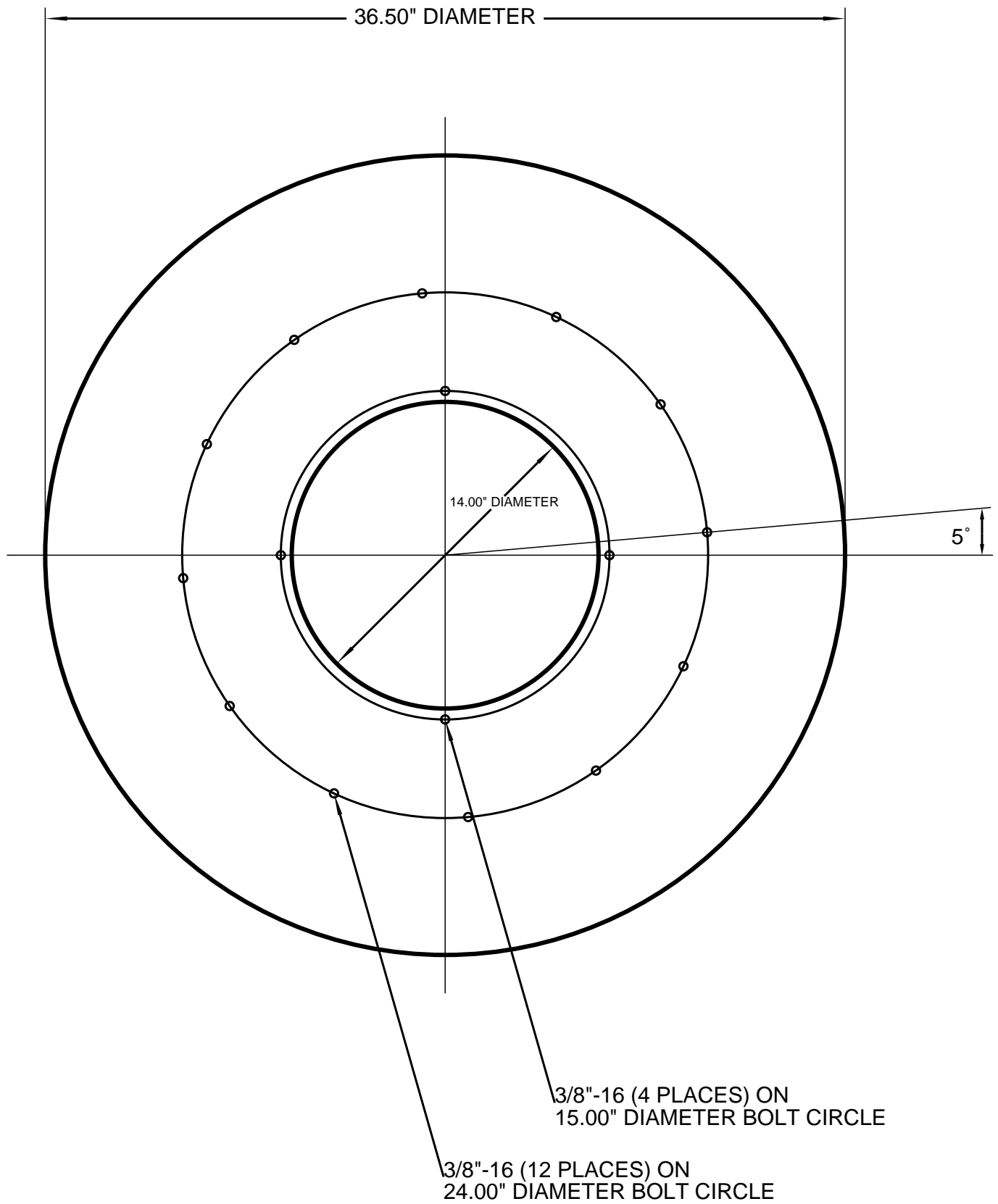


Figure 6.4: Layout of the 2.2-m Cassegrain instrument mounting flange

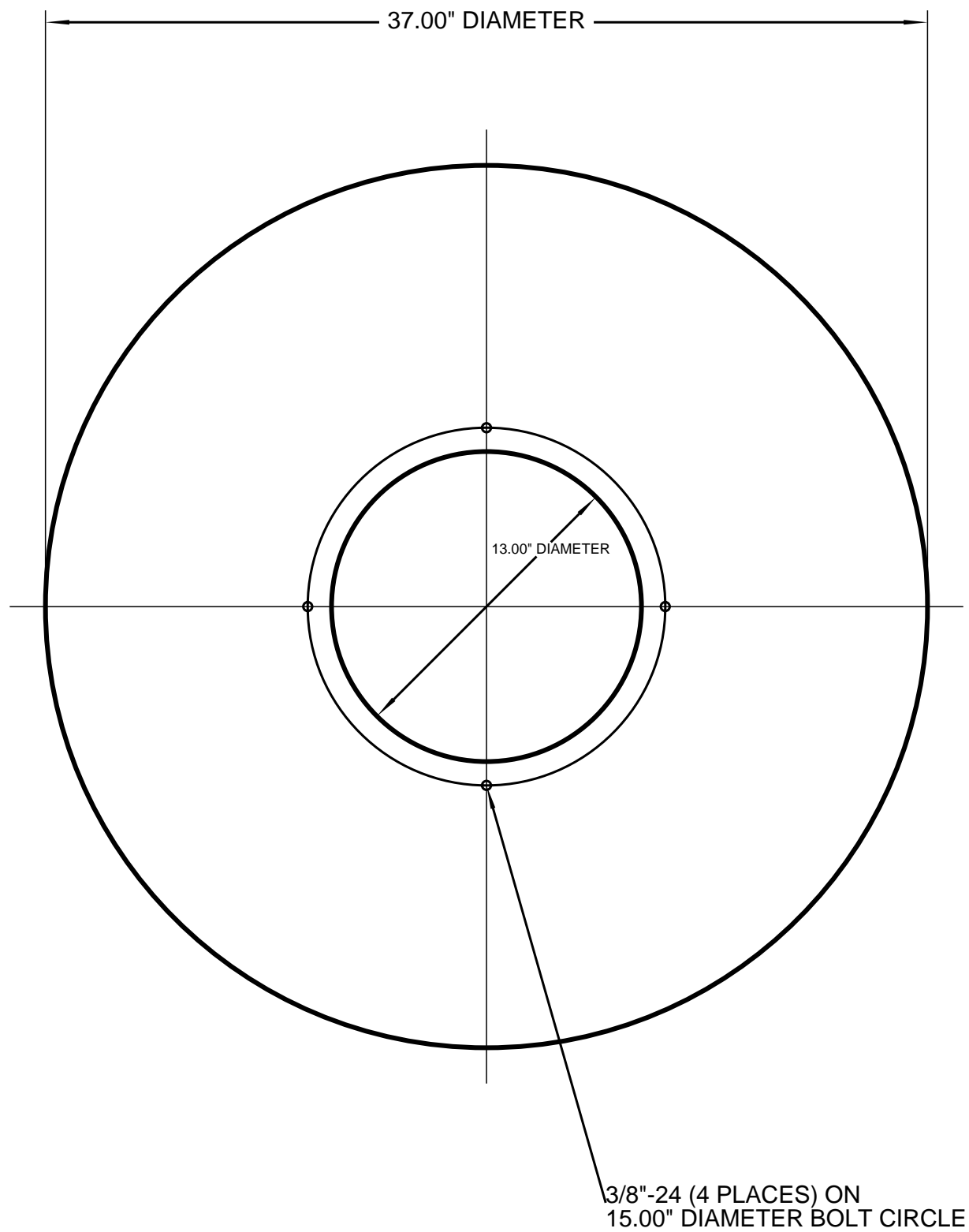


Figure 6.5: Layout of the 2.2-m broken Cassegrain instrument mounting flange

control (up, down, left, right), and a monitor for telescope guiding which is done via a handset attached directly to the telescope. Some space remains on the platform for additional equipment and, when required, an additional electronics rack or small table can be accommodated. Cables from equipment at the Cassegrain focus to the platform should be at least 8 m (25 ft) long to permit stowing the telescope in the horizontal position when the platform is down. Left and right motions of the platform should be used only with simultaneous up or down motions, and extreme care must be taken to avoid hitting the yoke counterweight tube whenever the telescope is away from the zenith.

6.2.3 Control Room

Especially large or temperature-sensitive components should be placed in the heated Control Room, or alternatively in the Control Support Room below, and connected by cable to the equipment at either the Cassegrain or coudé focus. Communication between the focus position and the Control or Control Support Rooms is by microphone. Visiting observers wishing to locate equipment in the Control Room must indicate their plans on the “Visiting Observer Information Sheet”. Minimum cable length from the Cassegrain focus to the Control Room is about 18 m (60 ft), and to the Control Support Room, about 26 m (85 ft). Fifteen unused coaxial cables are strung from the Cassegrain focus through the telescope to the Control Support Room. They are about 46 m (150 ft) long.

6.2.4 Coudé Focus

The coudé focus is reached by flipping the $f/10$ – $f/34$ top-end ring (manually), and by inserting the tertiary mirror (remotely) with the rotator set to 270° . Mirrors 4 and 5 are permanently mounted, and this changeover can be achieved in about 30 min for special applications.

The coudé focus travel limits are from approximately 2.5 m (8 ft) ahead of the slit to approximately 5.5 m (18 ft) behind the slit. The polar axis terminates in an instrument mounting flange containing four $\frac{3}{8}$ in, 24 tapped holes equally spaced on an 11 in diameter bolt circle.

The slit position angle is given by the following equation:

$$PA = HA - Dec + 36^\circ \quad (6.1)$$

The normal focus encoder position is approximately 12050.

6.2.5 Fiber-optic Audio-Video link

A fiber-optic audio video link has been installed between the 2.2-m telescope and Hale Pohaku. Diagrams showing this are in Figures 6.6 and 6.7.

We presently have three cameras at the summit. One of these will be installed to look outside, another will be installed in the dome, and the third is installed in the control room. The outside and dome cameras are black-and-white cameras, and work well in low light levels. The camera in the control room is a color camera. There are three microphones in the control room—one for the observer, one for the operator, and a lavalier microphone which can be clipped onto your shirt for hands-free use (when using this microphone, take care—you need to remove it when you leave the control room!). A color monitor in the control room shows the video image coming from Hale Pohaku, and an amplifier and speakers allow you to hear the person at Hale Pohaku.

At Hale Pohaku, a microphone, color camera, color monitor, and amplifier and speakers are all located in the 2.2-meter telescope office. This link provides high-quality two-way audio-video communication between the summit and Hale Pohaku.

At the summit, an audio-video switcher allows selection of different cameras and other video and audio sources. The switcher may be operated manually, or can be operated remotely using the program *videoi* on *tycho*. We intend to connect the summit VCR to this system to permit remote diagnosis of problems via this link. We are presently exploring a lower-bandwidth extension of this link back to Manoa via the existing T-1 computer link.

HALE POHAKU

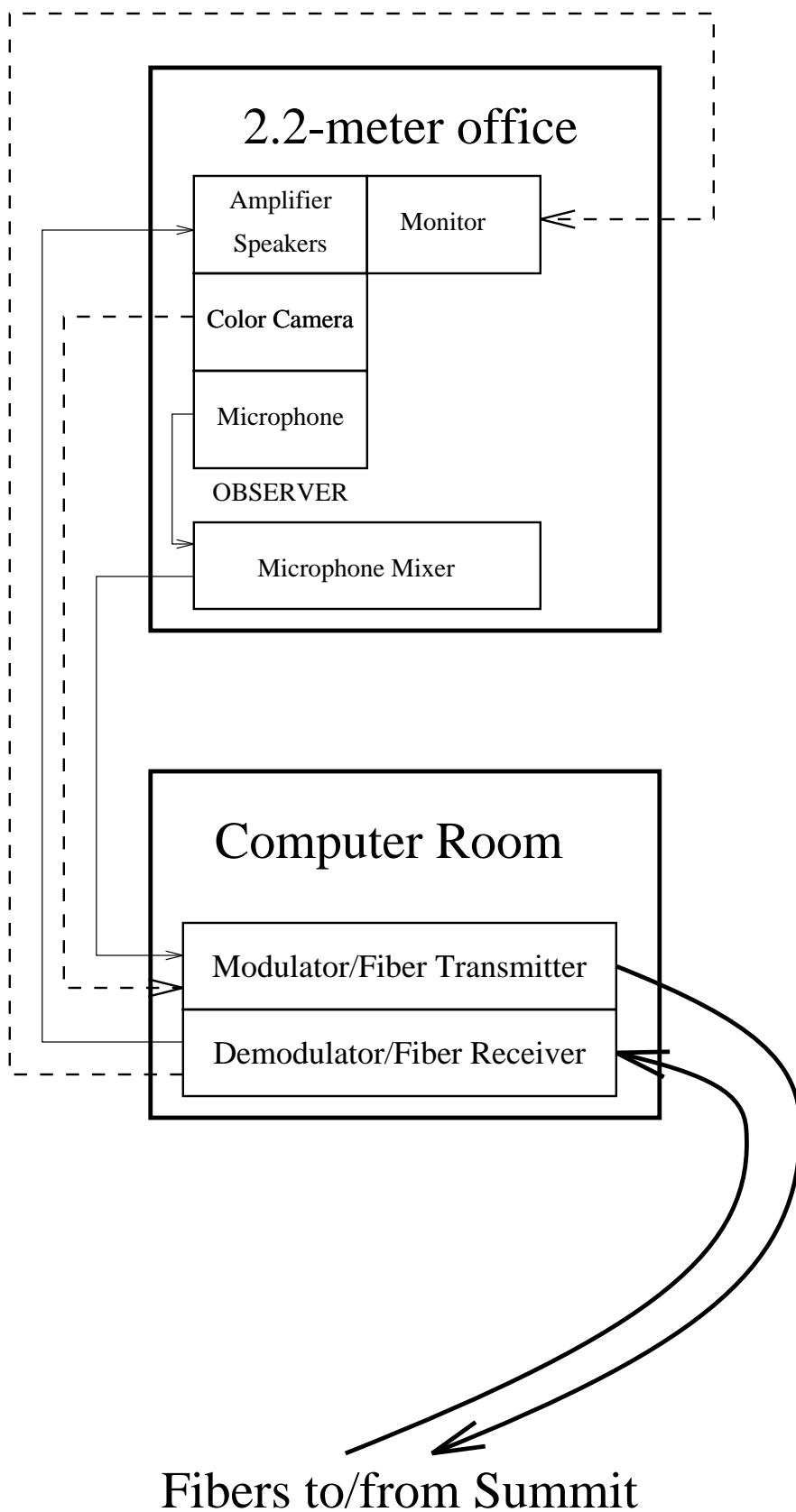


Figure 6.7: Block diagram showing the audio and video equipment at Hale Pohaku

Chapter 7

INSTRUMENTATION

7.1 UH Telescope imaging scales and field sizes

Table 7.1 shows the imaging scales, pixel and field sizes for UH optical CCDs and infrared detectors (QUIRC) in a number of possible configurations on various telescopes on Mauna Kea.

Table 7.1: Imaging scales and field sizes

Telescope	Focus	Scale (arcsec mm ⁻¹)	Orbit 2048		Tek 2048		QUIRC	
			pixel (arcsec)	field (arcmin)	pixel (arcsec)	field (arcmin)	pixel (arcsec)	field (arcmin)
25cm	f/10	83					1.70	29
61cm	f/15	22.7	0.34	11.6	0.55	18.6	0.462	7.88
	f/35	9.75	0.15	5.0	0.23	7.99	0.198	3.39
2.2m	f/10	9.17	0.14	4.7	0.22	7.51	0.187	3.18
	f/6.4 (Z135mm) ¹	14.3	0.21	6:	0.34	6:	—	—
	f/31	3.0	0.045	1.54	0.072	2.46	0.061	1.04
CFHT	f/8	7.17	0.11	3.67	0.17	5.87	0.146	2.50
	f/35	1.71	—	—	—	—	0.035	0.59
IRTF	f/35	1.95	0.029	1.00	0.047	1.60	0.040	0.68

Notes:

¹ The Zeiss 135mm lens is assumed to be used in conjunction with the Wide Field Grism Spectrograph (WFGS) as a focal reducer/spectrograph. Note that the field of view will be defined by vignetting of the focal reducer, and is approximately 6 arcmin.

7.2 2.2-m Cassegrain guider and instrument mount

7.2.1 Instrument Rotator

The Cassegrain focus is provided with a (manually operated) instrument rotator which is capable of supporting 230 kg (500 lb) with a maximum moment of 170 kg m (1200 ft lb). Figure 7.1 shows the new slide-mounted 19-inch electronic rack system, which is adjusted by the crew to provide balance for different instrument configurations. The rotator, racks and guider can normally be rotated by ± 100 degrees from the default orientation (270 degrees) to permit orientation of a spectrograph slit at any position angle, or of the guide probe dichroic to access guide stars without blocking the science beam. Cassegrain rotation requires careful two-person operation with the telescope at zenith, to avoid stretching cables, and takes about 15 minutes.

The nominal f/10 Ritchey-Chrétien focus lies 111 mm below the guider instrument mount surface. At f/10, instrument foci more than 50 mm below this will result in slight off-axis coma. The nominal f/31 focus is equivalently placed, but has considerably more focus latitude.

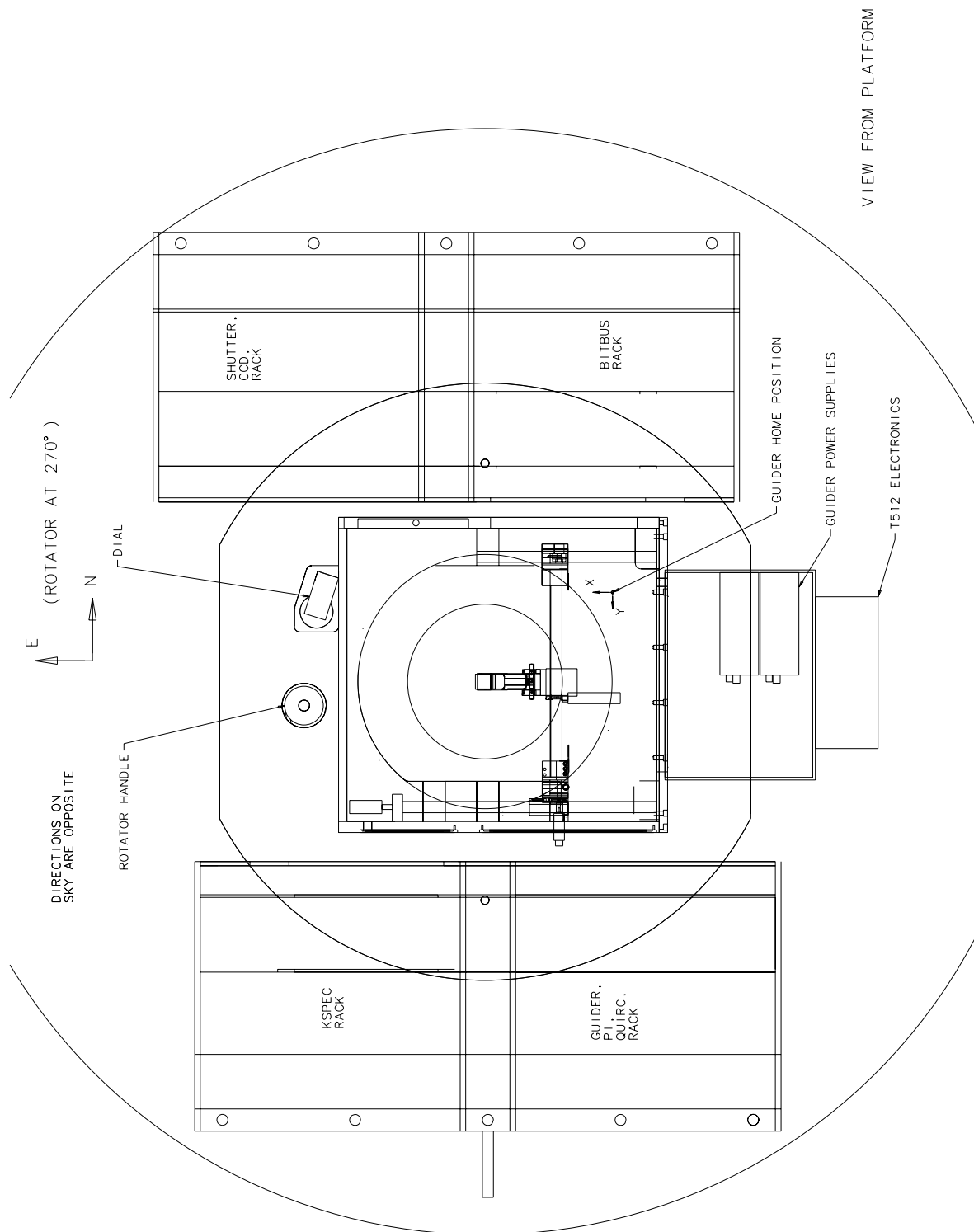


Figure 7.1: UH 2.2-m Cassegrain guider and instrument racks, viewed from below

7.2.2 CCD guider

A new CCD guider was installed in 1994 to replace the older ISIT TV system. It accesses guide stars over almost all the Cassegrain field, works to fainter limiting magnitudes, and provides both telescope guide signals (f/10 and f/31) and fast guide signals to the f/31 tip-tilt secondary (see below). Figure 7.1 illustrates the layout of the guider X-Y stage, pick-off probe and guide CCD camera. In this illustration, the guider is shown with the science instrument removed, and with the pick-off probe on-axis (in a typical configuration for on-axis tip-tilt guiding at f/31).

Operation of the guide X-Y probe and CCD camera focus is controlled by the program *Atlas* running on a NeXT computer *viper* in the control room. Operation of either the telescope guider at f/10 (program *MiniOtto*), or telescope and fast-secondary guider at f/31 (program *Otto*) is controlled by the same NeXT (*viper*). Graphic visualization of the Cassegrain guider environment and some guide probe functionality is integrated into the telescope user interface program *tsi* (see below) which runs on a Sun computer (*tycho*) in the control room.

The guide probe moves over a 47×40 arcmin field at f/10 (approximately 16×13 arcmin at f/31), and can access guide stars anywhere in that field. The guide probe currently consists of a 75 mm diameter dichroic (6.35 mm thick), oriented at an angle of 45° to the optical axis. The dichroic transmits wavelengths longer than 720nm, and reflects light with wavelength shorter than 720nm. The reflected light is focused on a Tektronix 512×512 CCD, which is perpendicular to the science beam and parfocal with the science instrument. This arrangement permits both off-axis guiding in any configuration, and on-axis guiding with an infrared science instrument (the science beam is shifted slightly, and the telescope focus lowered by insertion of the dichroic).

Guide CCD focus travel currently extends from 4 mm above nominal focus to 26 mm below. For f/31 instruments with a low focus, a 75 mm focal length converging lens can be inserted before the guide CCD to change the focus range to 12–150 mm below nominal. Insertion of the lens changes the pixel scale on the guide camera (varies with instrument focus depth), but does not change the scale of the probe movement on the sky. Lenses with focal lengths of 100 mm (range 8–67 mm) and 150 mm (range 5–32 mm) are also available. The longer focal length lenses vary the pixel scale on the guide camera to a lesser degree.

Guide star acquisition consists of a short full-frame guide CCD exposure to identify the guide star position. The star is then marked by the operator, and the probe or telescope position adjusted to place the starlight accurately on a small, predefined subframe or quad-cell. The subframe typically consists of a 5×2 readout area, each consisting of 15×15 physical CCD pixels (each $27 \mu\text{m}$ square). The first 2×2 subpixels are discarded because of readout noise, the next 1×2 subpixels form the bias area to one side of the star, and the last 2×2 sub-pixels form the quad-cell itself (7.4×7.4 arcsec at f/10, 2.4×2.4 arcsec at f/31). Guiding consists of reading this subarea subtracting bias from the 4 quad-cell signals, computing the centroid in 2 directions, and using these signals to guide the telescope and tip-tilt mirror when in use. The quad-cell area is typically in the center of the CCD for f/10 guiding, but very close to the readout corner for added speed during fast guiding (for tip-tilt guiding, readout is typically 20–100 Hz).

Guiding at f/10 consists of sending slow guide signals (1–2 Hz) to the telescope, which ensures accurate tracking and removal of *some* telescope vibration. Guiding at sidereal and non-sidereal rates is possible.

Guiding at f/31 consists of sending fast guide signals to the f/31 tip-tilt secondary, which has an operational range of ± 5 arcsec, and slow guide signals to the telescope when the tip-tilt secondary is significantly displaced from its central position. The speed of the fast guide loop is determined by the guide star exposure time, which typically varies from 200ms (13mag) to 5ms (9mag), corresponding to ~ 4 –150 Hz after readout overhead.

Fast guiding will remove telescope vibration and some atmospheric image motion. Best results are obtained with a bright, on-axis guide star. Diffraction limited images at *K* (FWHM=0.25'') have been obtained in long exposures, and images with FWHM=0.20'' have been obtained in the *H*-passband. Significant image improvement is usually obtained with fainter guide stars and guiding 2–5 arcmin off-axis.

More information on the new autoguider may be found at:

<http://ccd.ifa.hawaii.edu/docs/auto.html>

7.2.3 Instrument mount bolt circle

The new instrument mount consists of 3/8-16 tapped holes at regular 30 degree intervals on a 20-inch bolt circle.

7.3 tcsi—user object selection interface

7.3.1 Telescope Control System Interface—tcsi

tcsi is an X-window, event-driven interface program which provides communication between the user and/or Telescope Operator (TO), the 2.2-m Telescope Control System (TCS) and the new offset guider (*Atlas*). Users can select objects and stars, find appropriate photometric standard stars, and send slew requests for them to the TCS. Users can also schematically display their object fields and available guide stars (GS), select a GS and send the ATLAS guide probe to it (before or while the telescope is slewing).

Prospective users can create or edit their object-list and display the output from *tcsi* on their own workstation prior to their run. Users can pre-examine object/GS fields, preselect standards and plan spectrograph rotator angles, for example. *Slew* and *Atlas* requests are disabled when *tcsi* is operated remotely.

Please note that we prefer users to keep their object lists on *halley* rather than *tycho* which is the Telescope Operator's workstation. The fields are name in columns 1–12, RA as *hh mm ss.s* after column 13, Dec as $\pm dd mm ss.s$, Equinox as *yyyy.y*, followed by *comments*, which are ignored. The name field can exceed 12 cols if there are no embedded spaces past the 11th column; coordinates can be separated by spaces, commas, colons or tabs (which can cause uneven presentation), and the +sign is optional for northern declinations. The default equinox is 1950.0, and the maximum number of objects is 500.

Examples of the *tcsi* window and of the *sm* Cassegrain field graphics (at f/10 and f/31) are shown in Figs 7.2, 7.3 and 7.4.

7.3.2 Starting tcsi

tcsi runs on the 2.2-m control workstation *tycho*, which also stores all the catalog information. It can be run also from *wekiu* in the 2.2-m control room (*slew* and *Atlas* requests permitted), or from a workstation at Hale Pohaku or Manoa running X11 (*slew* and *Atlas* commands disabled). Invoke the program by typing:

```
xhost tycho
```

in your workstation console window, then

```
rlogin tycho -l obs
```

Password: (available from TO or Richard Wainscoat in Manoa)

```
setenv DISPLAY <workstation>:0.0
```

```
tcsi objectlist & (use your own file objectlist on tycho), or one of the files in that directory to try it out).
```

This will open the main *tcsi* window on your X-workstation. The window has four main sections and an optional *sm* display window (examples are shown in Figures 7.2, 7.3, and 7.4).

7.3.3 tcsi windows

1. The buttons near the top control the user's file; a subwindow below shows the contents of the file. The user's file name is shown in the top panel, and a new file can be selected by editing the *Object File* name domain, then pressing the *New File* button. An object is selected by clicking the mouse-cursor in the user file subwindow; long files can be scrolled with the slider bar to the right. **Note** that objects and/or coordinates needed quickly can be simply typed into the object sub-window directly, but will vanish when the process quits unless the file is saved. It is preferable to add extra objects by editing the user file, and pressing *New File*.

A SLEW request to the selected object is generated (from privileged workstations) by pressing *Get Object*. The telescope will not slew until the request is approved by the Telescope Operator.

2. The second section contains buttons for finding stars near to objects or the current telescope position. Stars from the SAO, BSC, GSC or photometric standard (optical and infrared, bright or faint for each) catalogs can be selected by pressing the left mouse button on the appropriate button. For the selected catalog, *Object Star* finds the 8 stars nearest to the selected object, *Local Star* finds the 8 stars nearest to the current telescope position. Select a star by clicking the mouse-cursor on a star in the star subwindow. Entering a close match (number or name) to a known star in the *Star:* field and pressing *Named Star* will search the database(s) for that star, and display the star (automatically selected) and 7 near neighbors if it is found. The display format includes name, coords, epoch, magnitude and angular distance from object, star or position in degrees. Standard display includes *V* and *V – I* for optical or *K* and *J – K* for infrared standards.. Guide star display includes positional error (in arcsec)/number of measurements, but this is optimistic for bright guide stars.

Get Object)		New File)		Object File: ajplist		Quit)	
c1613+4235	16 13 43	+42 35 18	1950.0	z=0.447			
A2397	21 53 38	+01 04 26	1950.0	z=0.219 *			
c2140+0341	21 40 52	+03 41 30	1950.0	z=0.276			
c2151+0153	21 51 30	+01 53 06	1950.0	z=0.232			
c2153+0451	21 53 54	+04 51 18	1950.0	z=0.44/37			
c2153+0059	21 53 56	+00 59 36	1950.0	z=0.230			
c2154+0508	21 54 12.0	+05 08 24	1950.0	z=0.333 *			
c2155+0334	21 55 19	+03 34 12	1950.0	z=0.820			
c2158+0351	21 58 14.0	+03 51 00	1950.0	z=0.445 *			
c0016+1654	00 15 58.3	+16 09 37	1950.0	z=0.54 *			
c0020+0407	00 20 13.0	+04 07 54	1950.0	z=0.698			
c0024+1653	00 24 00	+16 53 10	1950.0	z=0.391 *			
A370	02 37 26	-01 46 51	1950.0	z=0.373 *			
c0317+1521	03 17 13.0	+15 21 06	1950.0	z=0.583 *			
HDF1	12 36 49.4	+62 13 46	2000.0				

Object star)		SAO		HR-BSC		GSC		optSTD		irSTD		Local star)	
Get star)		Named Star)		Star: PG2349		Fnt		Brt					

FS 7	02:54:47.20	00:06:39.0	1950.0	10.940	0.165	4.7
FS 8	02:55:12.90	00:04:04.0	1950.0	8.313	0.766	4.8
FS 9	02:55:38.80	00:58:54.0	1950.0	8.266	0.884	5.3
FS 6	02:27:39.20	05:02:34.0	1950.0	13.374	-0.135	7.2
FS 4	01:52:03.70	00:28:20.0	1950.0	10.264	0.292	11.
FS 5	01:52:04.70	-07:00:47.0	1950.0	12.342	-0.007	12.
FS 10	03:46:17.40	-01:07:38.0	1950.0	14.919	-0.170	17.
G4697-01240	02:39:59.04	-01:34:00.2	2000.0	13.52	0.3/1	

Object GS)		F10		F31		Star GS)		Local GS)	
CassRot	270.0	HomeX	130000	/	✓	Tek	Orbit	Quirc	OLD
SlitPA:	0.0	HomeY	106000	/	✓	off	Dichroic		NEW
SetRot:	270.2	WFGS	FOS	HARIS	KSPEC	OFF	SM	ID	XY

G4698-00876	223782	83488	12.19	1.2/1
G4697-00707	24686	145428	12.64	0.4/2
G4697-01240	129886	103539	13.52	0.3/1
G4697-01177	169495	114879	13.89	0.3/1
G4697-01237	110097	143580	14.29	0.3/1
G4698-01152	23461	99621	14.55	0.4/2
G4698-00897	51396	7076	14.77	0.4/2

spec OK				
A370	02 37 26	-01 46 51	1950.0	z=0.373 *
16 close stars, 7 available to guider				
A370	02 37 26	-01 46 51	1950.0	z=0.373 *
16 close stars, 7 available to guider				

Figure 7.2: UH 2.2-m User interface tcsi

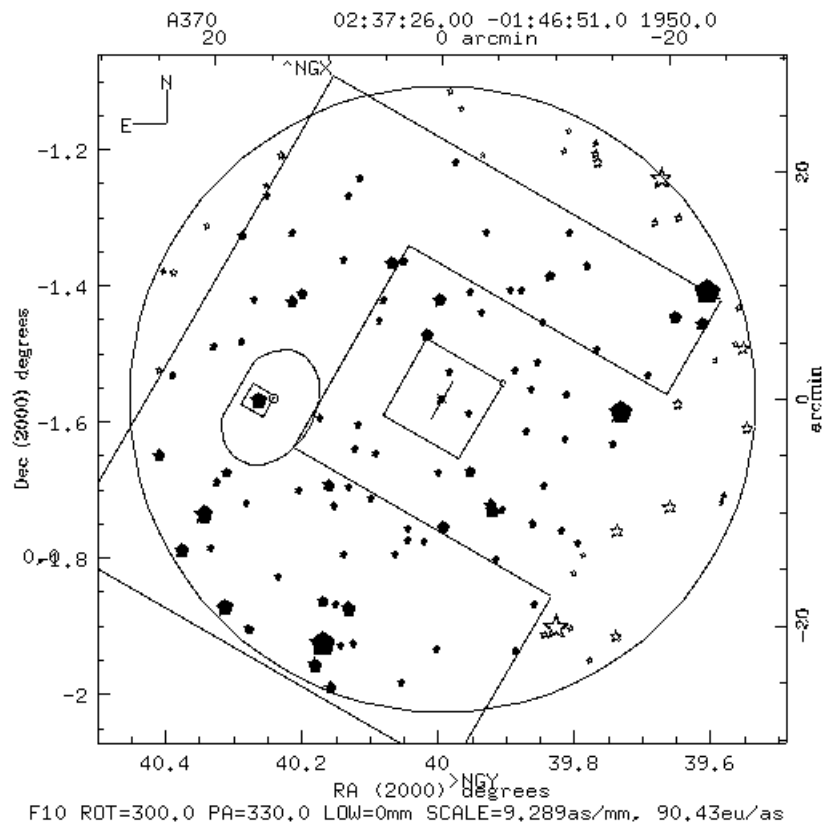


Figure 7.3: tcsi SM f/10 cassegrain display

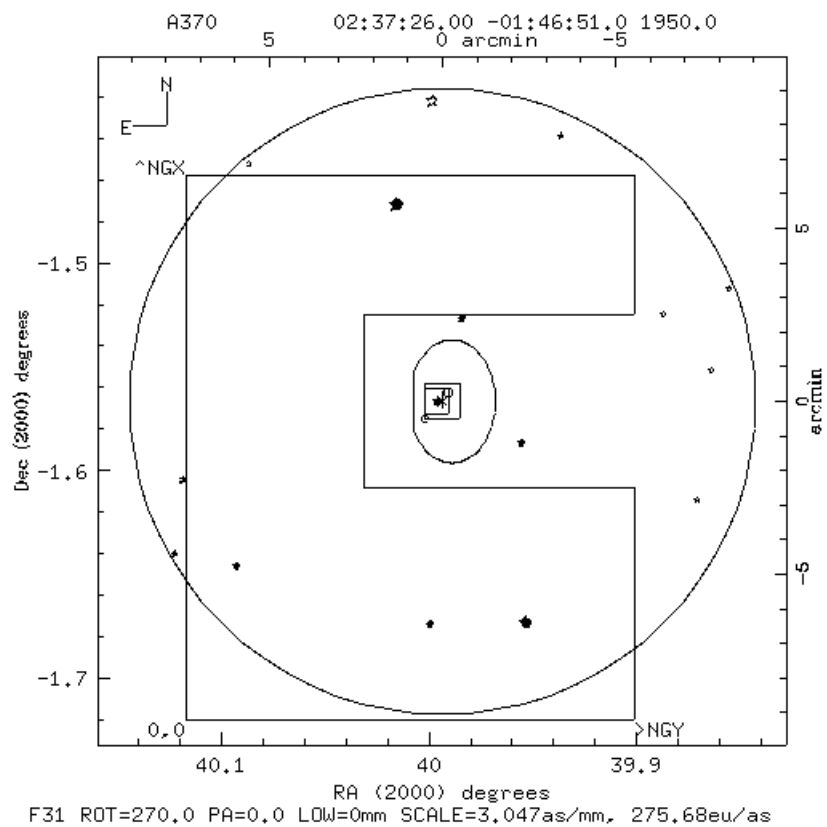


Figure 7.4: tcsi SM f/31 cassegrain display

GSC refers to the HST Guide Star Catalog (which is read from CD-ROM). The bright optical standards are from Landolt, AJ, 88, 439 (1983), and the faint optical standards are from Landolt, AJ, 104, 340 (1992). The bright infrared standards are from Elias et al., AJ, 87, 1029 (1982), and the faint infrared standards are from the unpublished UKIRT list.

Get Star generates a SLEW request for the selected star, if permitted.

3. The third section contains telescope and guider configuration buttons, guide star (GS) selection buttons and a sub-window which shows the 8 brightest guide stars. *Object GS* finds the 8 Guide Stars nearest to the selected object. *Star GS* finds the 8 Guide Stars nearest to the selected star. *Local GS* finds the 8 Guide Stars nearest to the current telescope position, but this will include telescope pointing errors, so it is preferable to use *Object GS* or *Star GS* where possible. The display format is name, *Atlas* X-Y position, magnitude, positional error in arcsec/number of measurements. Note however that Guide Stars brighter than 10 are quite likely to have positional errors > 1 arcsec due to photographic plate saturation. Use bright stars for simple mosaic/dithers, use SAO or faint Guide Stars for accurate positions.

The guider magnitude limits are approximately $V = 8$ at the bright end (guider CCD exposure 5–10 millisecc, 80–120 Hz frame-rate with good S/N but avoiding saturation) to $V = 15$ at the faint end (200–250 millisecc exposure, 4–5 Hz frame rate, with adequate S/N). The guider display background color changes from black (OK, star – background > 3000 DN/frame), to green (warning, $1500 < \text{DN} < 3000$), to yellow (failure, $\text{DN} < 1500$, no guide signals transmitted). If the signal is too faint, increase the exposure (decrease the frame rate) or find another guide star.

The default configuration is f/10 focus and Tek 2048 detector; selecting f/31 focus changes the scale appropriately and selecting another detector changes the size of the science field, which affects the limits to the probe position.

The optional spectrograph buttons (WFGS or FOS at f/10, HARIS or KSPEC at f/31) only affect how the Spectrograph Slit Position Angle (SlitPA, measured East from North on the sky) varies with the Cassegrain Rotator setting (CassRot, default 270°). When doing spectroscopy, a desired PA can be entered in *SlitPA*. The Cassegrain Rotator setting necessary to achieve this PA will then be displayed in *SetRot* (which includes a small zero point error). This will also update the new rotator setting in *CassRot*. However to actually achieve this, the telescope should be slewed to the Zenith, the observer should go up on the platform with the TO, release the T-bar clamp (towards the visitor gallery when at 270°), rotate slowly to the desired angle (checking all cables are free) and reclamp. Note that the rotator is designed to allow $\pm 100^\circ$ from the default 270° position, which permits all slit PAs.

4. The lowest section displays warnings, informational messages, and monitors the communications between *tycho* and the TCS. It is advisable to pay some attention to this window and, if there is unusual output there after sending an object's coordinates to the TCS, it is best to resend them.
5. An optional *sm* window is generated by clicking the *sm* button in the third (configuration) panel, and placing the new *sm* window somewhere convenient on the desktop. When the GS buttons are activated, a schematic presentation of the 2.2-m Cassegrain field (large circle), guider (horseshoe-shaped area) and detector field-of-view (central square) will appear here, arranged to match the focus, detector and Cassegrain rotation selected. The readout corner of the selected detector is marked with a small circle.

Available guide stars will also be drawn in the *sm* window, where brighter stars are drawn larger, and filled symbols represent stars accessible to the *Atlas* probe. The user/TO can visually select a guide star and determine its identity by clicking *ID*, then clicking the *sm* cursor on the selected GS; this will identify the selected GS in the star sub-window, and in the GS subwindow if the guider can access it.

From selected workstations, the user/TO can also direct the *Atlas* probe to a selected GS by clicking XY then clicking the *sm* cursor on a selected guide star. For on-axis guiding with an infrared science instrument it is advisable to select *Dichroic ON* to also display the probe, guider CCD and dichroic position with respect to the science field. Guide stars should be selected so that the dichroic either completely covers, or completely avoids the science field. The readout corner of the guider CCD is also marked with a small circle. Users should note that insertion of the dichroic lowers the telescope focus on the science detector (reduce f/10 focus by 7; reduce f/31 focus by 25 when inserting the dichroic).

7.4 f/10 secondary

The 2.2-m telescope was designed as a Ritchey-Chrétien wide-field telescope with a 45 arcmin coma-free field at the nominal f/10.14 Cassegrain focus. This wide-field capability is one of the strengths of the telescope, particularly in an era

of large optical and infrared arrays and mosaics, and provides a valuable wide-field complement to the large telescopes now on Mauna Kea. The f/10 secondary delivers 80% energy (Θ_{80}) within 0.4 arcsec over the full 45-arcmin field (approximately 300mm diameter at 9.17 arcsec/mm), but the curved focal plane requires a field flattener for imaging arrays larger than 100 mm in size.

The f/10 focus motor moves the mirror in encoder steps of $2.9 \mu\text{m}$, resulting in movement of the f/10 Cassegrain focal plane by $39 \mu\text{m}$, with increasing number indicating movement of the f/10 focal plane *towards* the primary.

7.5 f/31 secondary

The old f/35 infrared chopping secondary suffered from significant astigmatism and poor image quality, which rendered it useless for imaging work with the new generation of infrared arrays.

Site testing in the 1980s had indicated that the best intrinsic seeing on Mauna Kea (0.2–0.5 arcsec FWHM) was being degraded by existing telescope image profiles which were typically ~ 0.5 arcsec. These were produced by a combination of dome seeing, optics, optical misalignment with telescope position, and mechanical vibration. Dome seeing and alignment problems can be addressed by careful calibration and thermal management. The mechanical vibration intrinsic to an older telescope like the 2.2-m can only be addressed by incorporating a low inertia component which can be guided faster than the telescope resonant frequency (0.5–2 Hz)—a tip-tilt secondary.

Additional seeing improvements possible from Adaptive Optics (AO) depend on the ratio of telescope diameter to the Fried seeing cell size (which in turn increases with wavelength). The ratio D/r_o is typically large for large telescopes, even at longer wavelengths, requiring high order adaptive systems for significant improvements. However since D/r_o is small for the 2.2-m telescope, the simplest (tip-tilt) adaptive optics system can deliver $\sim 70\%$ of the gain possible with AO, provided that the static optical quality is maintained.

In 1989 it was decided to build a new high resolution secondary mirror for the 2.2-m telescope, to complement the existing wide-field f/10 capability, with the following characteristics:

- high optical quality to match the best seeing available on Mauna Kea (0.2–0.5 arcsec FWHM typically);
- small enough to permit fast tip-tilt guiding, but large (fast) enough to permit a reasonably large, coma-free field (~ 4 arcmin);
- remote collimation and focus with a hexapod mount to maintain optical alignment;
- concentrate on the ‘extended optical’ wavelength regime (0.3–2.3 μm), which corresponds to our main detector sensitivities (CCD and HgCdTe infrared arrays), and avoids the severe extra mechanical constraints required when chopping for thermal infrared background subtraction.

Extra-focal measurements of the 2.2-m primary were made in 1989 to accurately determine its surface figure. The measured conic constant was significantly different from the original manufacturer’s figure, but these results (Table 7.2) indicated an excellent surface which could deliver $\Theta_{80}=0.2$ arcsec with a secondary figured to remove the spherical aberration of the primary.

The choice of focus is a compromise between longer focus (small, lightweight secondary which is easier to tip-tilt) and shorter focus to minimize the off-axis coma. The compromise choice was a quartz f/31 secondary, specified to match our measured primary. This mirror was ordered from Optical Science Center (Tucson) and delivered in 1991. The f/31 secondary is slightly undersized (it illuminates 2.1-m of the primary), has a diameter of 211 mm and weighs 1.8 kg. The f/31 focus has coma which increases linearly with distance off-axis; at a distance of 2 arcmin off-axis, the coma amounts to 0.35 arcsec. The image scale is 3.0 arcsec/mm.

7.5.1 f/31 hexapod and Physik Instrumente tip-tilt platform

The f/31 high resolution Cassegrain focus is much more demanding (by a factor of 10 compared to the f/10 focus) in its requirements of primary-to-secondary separation, centering and alignment. Ideally it requires active control of both primary and secondary to compensate for telescope flexure across the sky.

A hexapod support system for the f/31 secondary was built at the IfA, and installed on the 2.2-m in 1993. The older f/35 top-end ring was retained, but the spider support mechanism, hub and hexapod positioner were all redesigned and built at the IfA, and installed in 1993.

The optics and solar groups at the IfA had successfully used a number of small tip-tilt platforms from Physik Instrumente (PI). Their experience led directly to the concept of a piezo-driven tip-tilt platform which was large enough to support and

Table 7.2: 2.2-m primary and f/31 secondary mirror optical specifications

	Primary	f/31 secondary	Notes
Diameter	2.2 m	211 mm	
Radius of curvature	12344.5 mm	-1293.6 mm	
Manuf. conic const.	-1.0497	-2.173	
Measured conic const.	-1.0535		
RMS surface error	40 nm	17 nm	
MAX surface error	120 nm	130 nm	
Sph. Aberration	-11 μ m	-20 nm	f/31 combination of 2 mirrors
Astigmatism	250 nm	150 nm	largest remaining error
Coma	150 nm	60 nm	
Triangular		220 nm	reduced to 60 nm with new air-regulator
Wavefront error		300 nm	~twice NTT, slightly less than CFHT

Table 7.3: PI S-380 Characteristics

	Mechanical	Focal Plane
Range	± 30 arcsec ($\pm 150 \mu$ rad)	± 5 arcsec
Resolution	0.05 arcsec (0.25μ rad)	0.008 arcsec
Residual Jitter	0.05 arcsec (0.25μ rad)	0.008 arcsec
First Resonance	600 Hz	
Total Mass	12 Kg	
Mirror+PI Dimensions	214×115 mm	
Power Dissipation	<2 Watts	

Table 7.4: Hexapod Specifications

DIMENSIONS	Diameter	200 mm
	Nominal Height	232 mm
	Central Hole Diameter	75 mm
	Net weight	7.3 Kg
	Max power input	3 Watts
RANGE OF TRAVEL	X/Y Motion (Collimation)	± 2 mm
	Z Motion (Focus)	± 12.5 mm
	Tip/tilt	± 0.5 degrees
RESOLUTION	Z Motion	1 μ m
	X/Y Motion	3 μ m
	Tip/tilt	8 μ rad (1.6 arcsec)
STIFFNESS	X/Y movement under load	2 μ m/kg
	Z movement under load	0.05 μ m/kg
	Repeatability & homing accuracy	1 μ m
	First Resonance with PI	300 Hz
	Max speed in Z-motion	0.4 mm/sec
	Typical speed in Z-motion	0.05 mm/sec

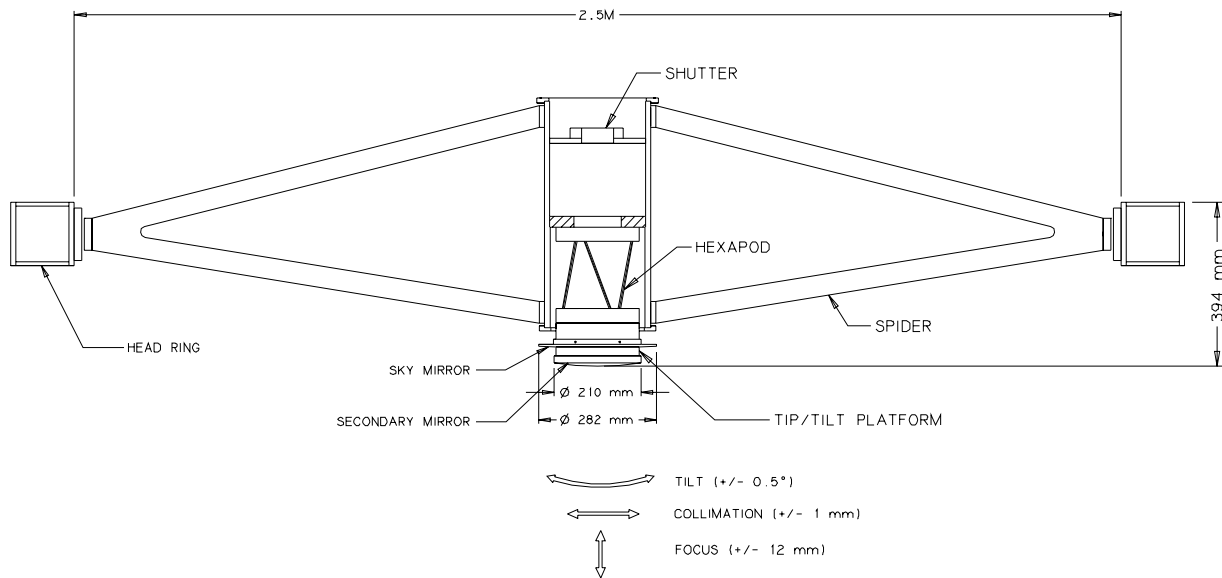


Figure 7.5: UH 2.2-m f/31 top end with hexapod and PI platform.

drive the f/31 mirror directly. PI delivered a 200mm device in 1991, which was at the time the largest such piezo-driven and momentum compensated device that PI had made.

Figure 7.5 shows the arrangement of the hexapod, fixed to the top plate in the hub, with the lower plate moving under servo control of the 6 legs. The PI platform is bolted to the lower plate of the hexapod, and contains 6 piezo stacks. The f/31 mirror is epoxied to 3 piezo stacks, which control the mirror fine motion; the other 3 move a counterweight in opposition to provide momentum compensation. Characteristics of the PI tip-tilt platform are listed in Table 7.3 and of the hexapod positioner in Table 7.4.

More information on the tip-tilt secondary mirror is available at: <http://ccd.ifa.hawaii.edu/docs/tiptilt>.

7.6 Focusing

7.6.1 Focus sensitivity to temperature

Both f/10 and f/31 focus encoders should *decrease* to maintain focus as temperature decreases, but the f/31 focus is 3 times more sensitive to temperature.

An ambient temperature *decrease* of 1°C caused the telescope tube to contract by 60 μm , bringing the mirrors closer. To compensate for this change, the f/10 focus must be *decreased* by 20 encoder units (each 2.9 μm). An f/10 focus decrease of 10 encoder units moves the focal plane up by 390 μm , which changes the f/10 image width by 39 μm (~ 2 pixels). Therefore, observers should try to focus to 5–10 units (f/10 focus resolution is ~ 2 units, $\sim 6 \mu\text{m}$), and refocus if the tube temperature changes by more than 0.5°C.

A 1°C temperature *decrease* requires an f/31 focus *decrease* of 60 units (microns) to compensate. An f/31 focus decrease of 10 μm moves the focal plane up by 1350 μm , which changes the f/31 image width by 44 μm (~ 2 pixels). Observers should therefore try to focus to within 5–10 μm (focus resolution is 1–2 μm), and refocus at f/31 if the tube temperature changes by more than 0.15°C.

7.6.2 Focus settings for common instruments

The nominal f/10 Ritchey-Chrétien (and f/31) focus lies 12.75 inches (324 mm) below the instrument rotator. The new guider and rack-mount plate have a depth of 8.125 \pm 0.25 inches (213 mm). Instrument focal plane positions for common instruments are listed in Table 7.5. Approximate focus settings for common instruments are listed in Table 7.6.

Table 7.5: Common IfA instrument and mount dimensions along optical axis

Instrument or Mount	Height	
	inch	mm
Rack Mount Plate	0.25	7
Atlas Guider	8.125	206
Rack+Atlas	8.375	213
Hippo Polarizer (HSPC)	1.65	42
Rack+Atlas+HSPC	10.025	255
Large Filter Wheel LFW	2.5	63
New Filter Wheel NFW	2.5	63
IfA CCD dewar	0.5	13
QUIRC	4.0	102
8K Mosaic CCD	4.0	102
Blue Beam+Filter Slide BBFS	2.1	52
Wide Field Grism WFGS	0.5	12
Tully Optical Bench HIFI	1.0	25
f/10 FOS	2.7	68
f/31 HARIS	2.7	68
f/31 KSPEC	6:	150:

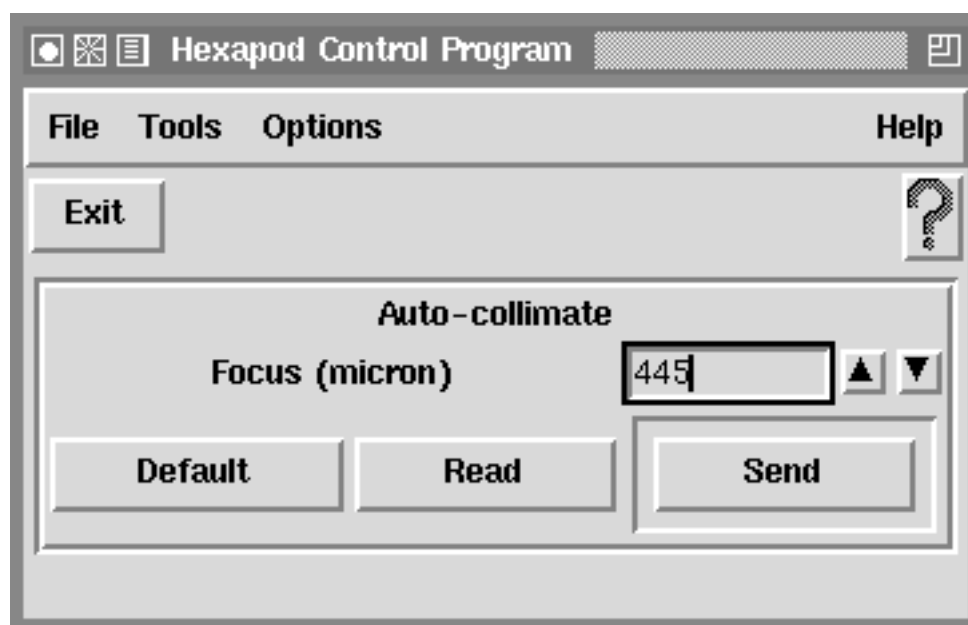
Table 7.6: Common IfA instrument configurations and focus settings¹

Rack Plate + Atlas + Instrument	Depth below Cass. Rotator (mm)	Focus encoder	
		f/10	f/31
HSPC+LFW+CCD	331	4850	120
Quirc	315	4450	0
HSPC+Quirc ²	357 ²	5530	310
HSPC+BBFS+WFGS(+CCD)	319	4650	
8K Mosaic CCD	315	4450	0
HSPC+FOS	323	4650	
HSPC+HARIS	323		60
KSPEC ²	363 ²		300
OHS	330		100

Notes:

¹ These focus encoder values are for a nominal ambient temperature of 0° C, and take no account of filters which may be included by the user. These focus values will vary with ambient (telescope tube) temperature as noted above.

² The Atlas guide CCD can move for focus from 4 mm above to 26 mm below nominal focus (320–350 mm). Instruments below this range require insertion of a 75 mm focal-length lens just before the guider CCD to achieve guide focus. This will change the scale in arcsec/pixel on the guide CCD, but not the telescope scale that the guide probe operates in.

Figure 7.6: *tkhex*—focus window

7.6.3 Focusing the f/31 secondary mirror

The f/10 mirror focus is operated via conventional push buttons which move the mirror in or out.

The f/31 secondary is focused and collimated by varying the lengths of the six legs which constitute the hexapod mount. The focus and collimation are controlled by the program *tkhex*. An example of the focus window of *tkhex* is given in Figure 7.6, and an example of the collimation window is given in Figure 7.7. Further information on *tkhex* is located at: <http://ccd.ifa.hawaii.edu/docs/hexapod/tkhex.html>

7.7 CCDs

CCDs are constantly being developed for the 2.2-m telescope; this manual contains a snapshot picture of the CCD status at the time of writing. The latest information can be obtained from the telescope newsletter or from support staff.

Most CCDs are presently controlled from a NeXT workstation (running Unix, and the NeXT windowing system). Control may shift onto different Unix workstations (perhaps with the X windowing system) at some time in the future. A typical view of the user interface is shown in Figure 7.8. The user interface is very easy to learn. Further details of the User Interface may be found at:

<http://ccd.ifa.hawaii.edu/docs/Ccd>

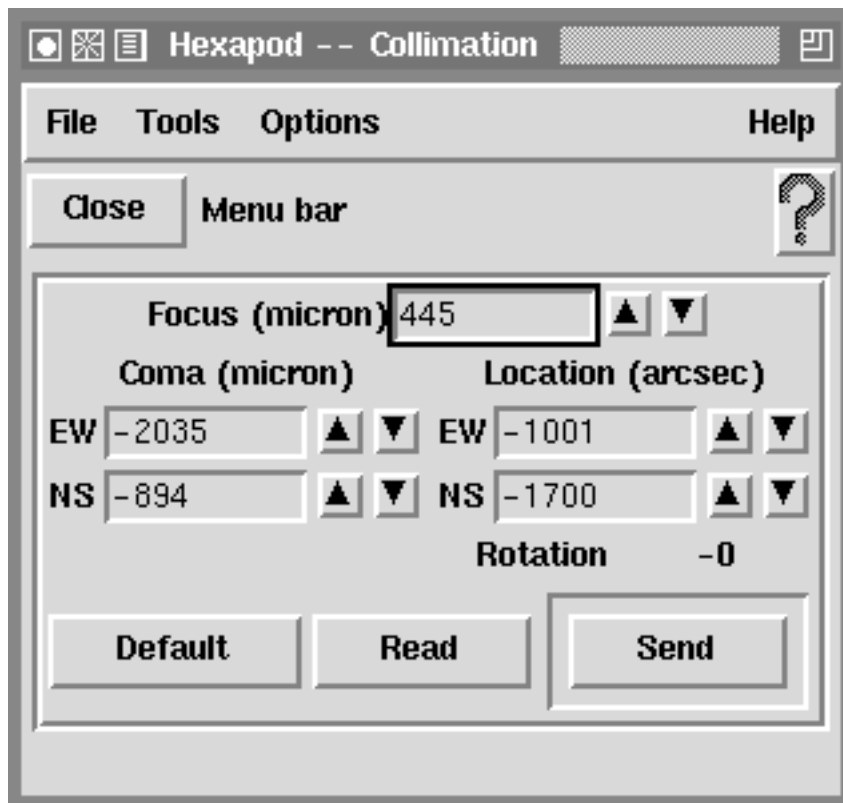
When used for direct imaging, CCD cameras can be mounted directly onto the large filter wheels (see Section 7.8). CCD cameras can also be mounted with optical components such as focal reducers on standard steel rails, generally referred to as ‘beams’, allowing one dimensional movement along the optical axis for inclusion of extra components. Beams are identified by their color, but differ only in their length, with the blue beam being longer than the green, and hence more appropriate for extended configurations.

All CCDs are mounted in similarly constructed dewars. The physical dimensions and overall construction of the standard CCD dewars is shown in Figure 7.9.

The CCDs currently in use or under development are listed below. Device characteristics (where available) are summarized in Table 7.7.

7.7.1 Tektronix 2048 × 2048 CCD

This is currently the optical detector of choice on the 2.2-m telescope; it is in use nearly every dark run. Cosmetically it is quite good, having only a few small flaws. Its 24 μm pixels give it an ideal scale at either f/10 (0.22'' pixels), or at f/31 (0.07'' pixels). It is thinned and back-side illuminated, resulting in a high quantum efficiency from blue through to 1 μm .

Figure 7.7: *tkhex*—collimation window

The quantum efficiency of our original Tektronix 1024×1024 CCD was measured in the lab. Its performance is shown in Figure 7.10. The quantum efficiency is over 90% at 750 nm, but is poor below 400 nm. The Tektronix 2048×2048 CCD has similar characteristics from 500 to 900 nm, but has higher QE in the blue.

7.7.2 Orbit 2048×2048 CCD

A new 2048×2048 CCD made by Orbit Semiconductor has been thinned by Mike Lesser at Steward Observatory. This chip has $15 \mu\text{m}$ pixels. It has high QE down to the atmospheric cutoff. Its QE is shown in figure 7.10. At the time of writing of this manual, this CCD had not been used at the telescope.

7.7.3 Loral 2048×2048 CCD

A Lumigen coated Loral CCD with useful area of 2048×1024 $15 \mu\text{m}$ pixels serves as a backup for the Orbit CCD.

7.7.4 8192×8192 mosaic CCD camera

A camera comprising of a 4×2 mosaic of 4096×2048 CCDs ($15 \mu\text{m}$ pixels) available for use on the 2.2-meter telescope. When used at $f/10$, it is normally binned 2×2 , yielding a 4096×4096 image, with $0.275''$ pixels, and a field of view of approximately $19' \times 19'$. A custom designed lens acts as both dewar window and field flattener. The CCDs in this camera are unthinned, and have very poor sensitivity in the blue. This CCD camera has an integrated filter slide, and three 150mm square filters (*V*, *R* and *I*) are available.

7.8 Filter Wheels and Filter Slide

When used for direct imaging, CCDs are normally mounted on one of two large filter wheels. Each filter wheel has four positions, and is remotely operable. In the older wheel (LFW), filters are inserted in custom design filter holders. These

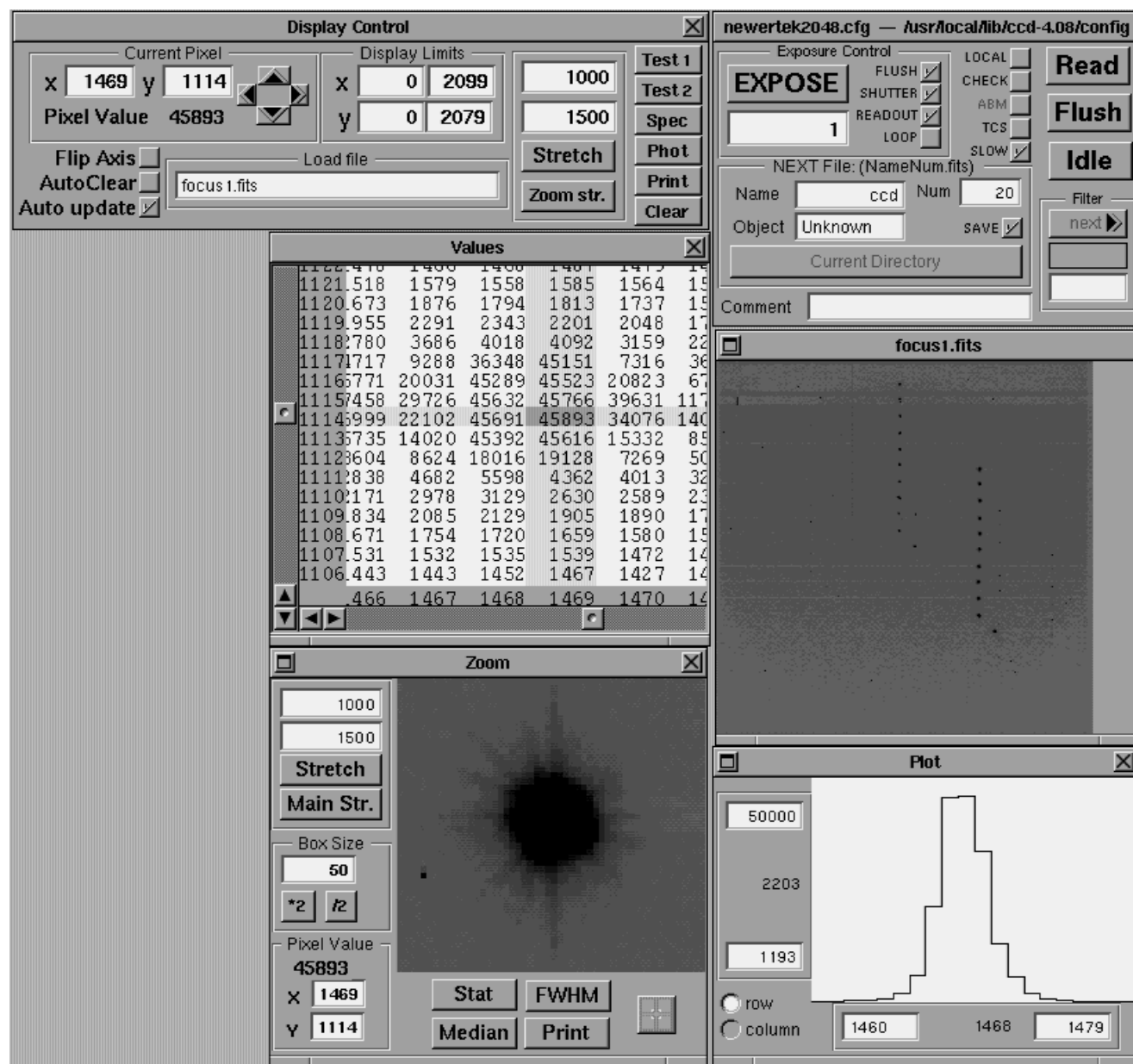


Figure 7.8: View of the CCD user interface, which runs on a NeXT workstation

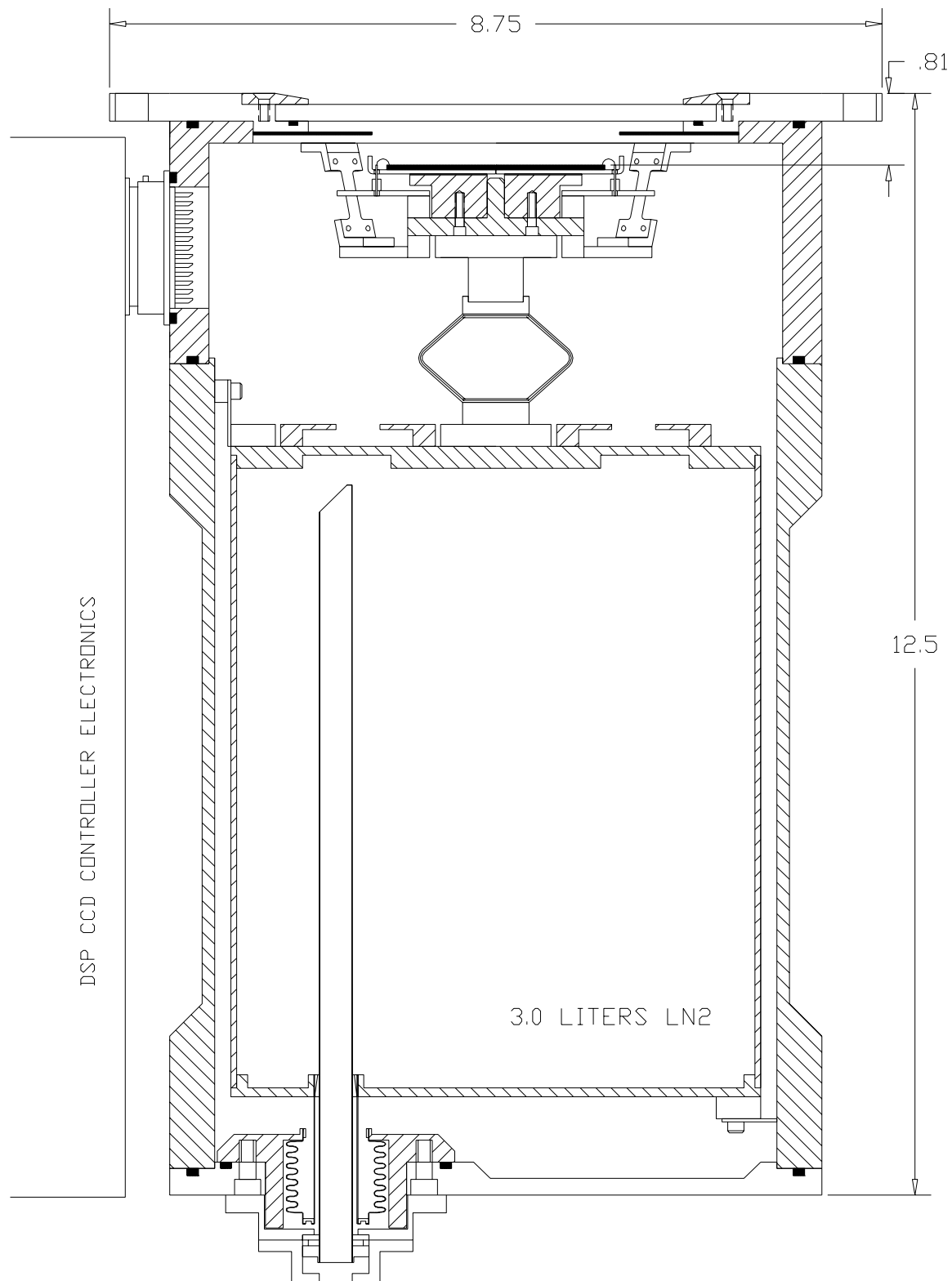


Figure 7.9: Physical characteristics of typical CCD dewars

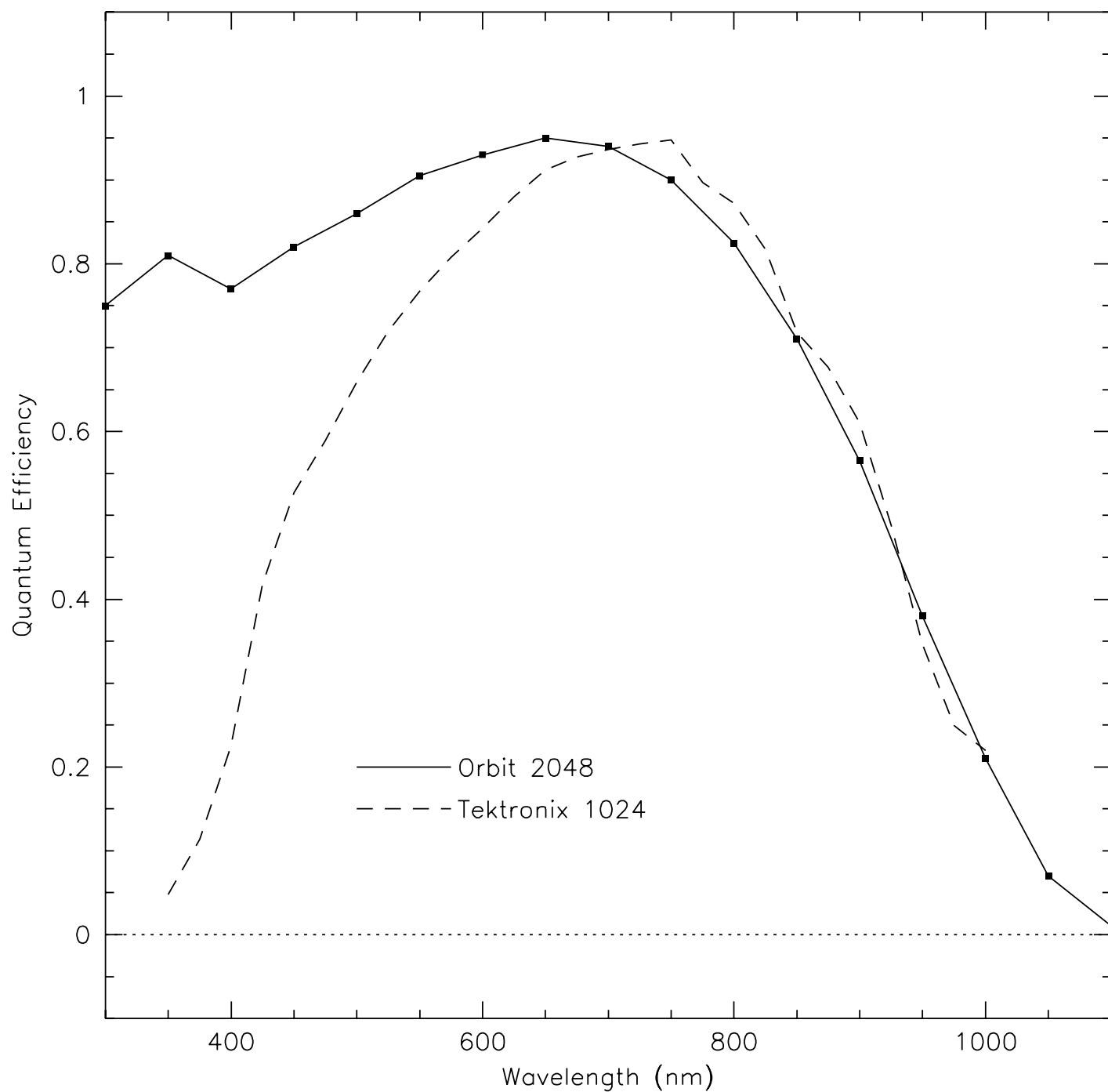


Figure 7.10: Measured quantum efficiency of Tektronix 1024 \times 1024 and Orbit 2048 \times 2048 CCDs

Table 7.7: CCD characteristics

Detector	Array Size	Pixel Size μm	Read Noise e^-	Dark Current $\text{e}^-/\text{pixel}/\text{sec}$	Gain e^-/ADU	Full Well ADU
Tek 2048	2048×2048	24	20		5.4	23,000
Orbit 2048	2048×2048	15				
Loral 2048	2048×1024	15	~ 10			
Tek 512	512×512	27		large		10,000
Mosaic 8192 †	8192×8192	15	5–20	0.1	~ 2.1	35,000–60,000

Note: † Characteristics are different for each chip in the 8k mosaic camera.

filter holders are designed to hold filters with 100 mm diameter, and typical thickness of 7mm. Adaptors are available for smaller filters (e.g., 50 mm square, 50 mm round). In the newer filter wheel (NFW), 100mm diameter filters are mounted directly into the wheel, without filter holders.

The shutter in the large filter wheel and in the new filter wheel is a Prontor E/100 magnetic shutter (part number 177 666). This is a *radially* opening shutter, with an aperture of 100 mm. Because it is so large, observers must take care to ensure that their exposures are long enough so that the shutter opening time is small relative to the total exposure. The specified open and close time for the shutter are both 34 ms. This means that for 1% photometry, exposures should be no shorter than $100 \times 68 \text{ ms} \approx 7$ seconds. Repeated usage of the shutter may have degraded its performance somewhat, so a more conservative approach is to limit the shortest exposures to 15–20 seconds. Particular care must be given to flat-field exposures. Twilight flats must be taken when the sky is dark enough so that these longer exposures do not saturate the CCD; for dome flats, the dome illumination must be low enough so that exposures of approximately 20 seconds do not saturate the CCD.

A manually operable filter slide, with space for four 50 mm square filters is also available; this can only be used in the “beam” configurations, in which the CCD is mounted on a beam, behind optical components such as the Wide Field Grism Spectrograph (WFGS).

7.9 Optical/UV filters

Standard *BVRI* filters are available (all 100 mm in diameter). These are based on the Mould *BVRI* system (KPNO—similar to Kron-Cousins). A U' filter, with central wavelength of 341 nm and bandpass of 32nm is also available. The U' *BVRI* filter set was designed to have the same optical thickness, so is parfocal—there is no need to adjust focus when changing filters.

These filters are all interference filters, and have high throughputs and sharp edges in their transmission curves. Transmission curves for this filter set are shown in Fig. 7.11.

Examples of color equations for these filters with the Tektronix 2048×2048 CCD are:

$$B = -2.5 \log(\text{Counts/Seconds}) + 24.156 - 0.155X + 0.141(B - V); \quad (7.1)$$

$$V = -2.5 \log(\text{Counts/Seconds}) + 23.825 - 0.088X - 0.058(B - V); \quad (7.2)$$

$$R = -2.5 \log(\text{Counts/Seconds}) + 23.837 - 0.045X + 0.006(B - R); \text{ and} \quad (7.3)$$

$$I = -2.5 \log(\text{Counts/Seconds}) + 23.339 - 0.096X + 0.011(B - I). \quad (7.4)$$

where X represents airmass. For this CCD/filter set, the B filter has an important color term (being significantly redder than the standard B filter). The V filter has a small color term—it is slightly bluer than the standard V filter. The color terms for the standard R and I broad-band filters are close to zero.

7.10 Infrared Cameras

The only infrared camera presently available is QUIRC, which uses a 1024×1024 HgCdTe array made by Rockwell. The array consists of 4 quadrants, each 512×512 , with pixel size $18.5 \times 18.5 \mu\text{m}$.

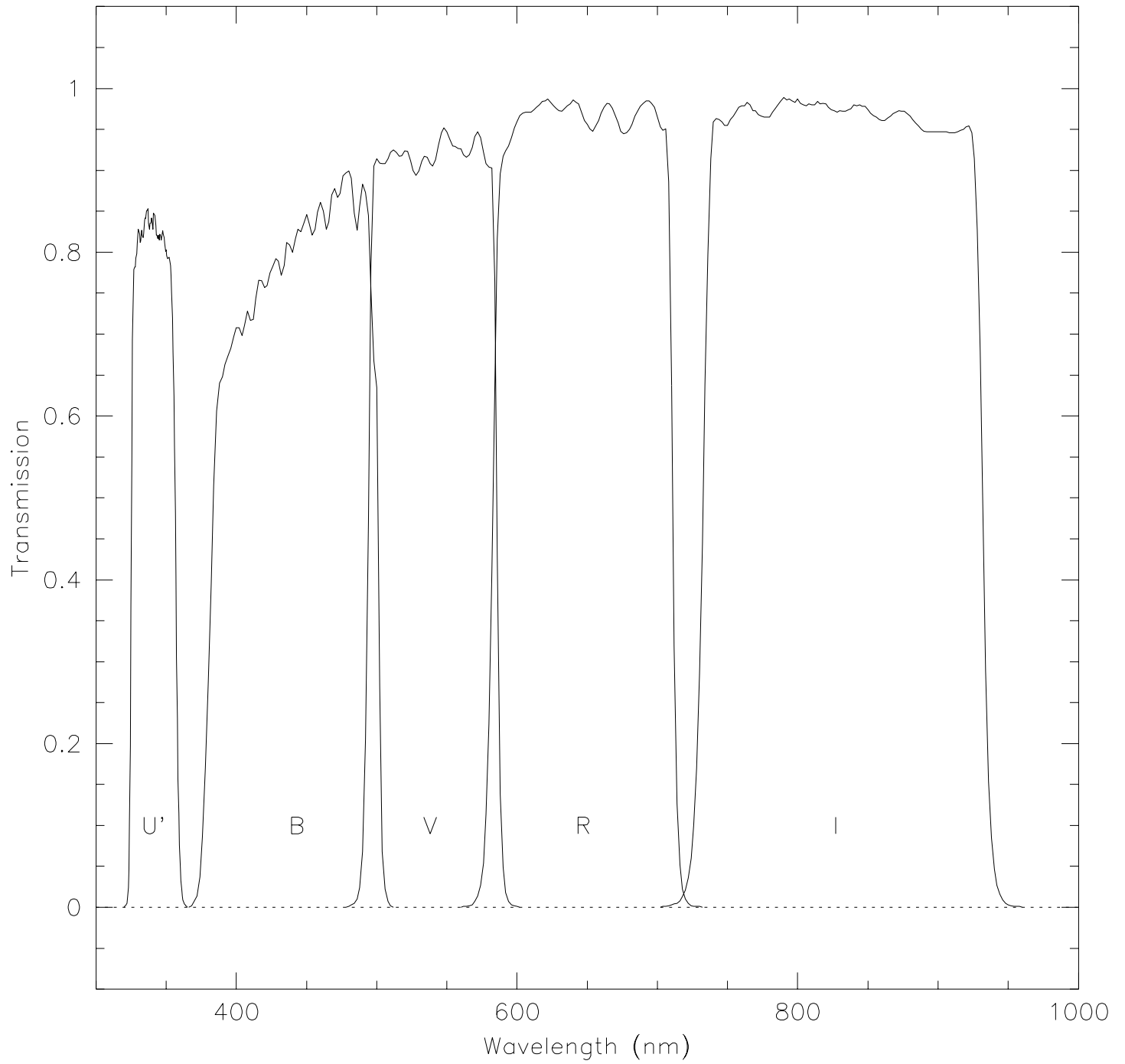


Figure 7.11: Transmission curves of optical/UV filters

7.10.1 QUIRC

QUIRC (QUick InfraRed Camera) uses a high quantum efficiency, low read-noise HgCdTe infrared array manufactured by Rockwell Science Center. The camera has reimaging optics which provide a magnification of 1.10, and a cold-stop is built into these optics. Four cold stops are available: one for each of the f/10 and f/31 foci of the 2.2-meter telescope (the f/10 cold stop is also used with QUIST), one for the f/8 focus of the CFHT, and one for the f/15 focus of the 61-cm telescope.

QUIRC is run from a command line interface on a Sun SPARCstation. The control program is currently called *qcdcom*. This program interfaces with the array and its associated electronics via a fiber-optic communication interface.

Data are written into FITS files with an effective gain of approximately $4e^-/\text{ADU}$. The array is roughly linear up to approximately 40,000 ADU; average pixel values in exposures should generally be kept to below about 20,000 ADU.

Short exposures should be avoided, because the shutter is a radially opening type, and because the shutter timing is uncertain at the 10 ms level. This means that, at least at f/10, faint standards should be used. The Elias standards need to be slightly defocused if used with broad-band filters at f/10.

Because of delamination concerns, QUIRC is always kept cold. Observers must take care to always fill the dewar properly. Normally, the dewar is filled at the beginning and end of each night. It has a hold time of approximately 24 hours, but this hold time is reduced when the telescope is slewed around the sky.

QUIRC has two filter wheels, each with 8 positions. Each filter wheel has one empty position, and one slot is occupied by a polarizer. Therefore, 13 positions in total are available for filters. Five of these positions are always occupied by broad-band filters (*J*, *H*, *K*, *K'*, and *HK'*). Filters for the 1–0 S(1) line of H_2 at $2.12\mu\text{m}$, for $\text{Br}\gamma$ ($2.16\mu\text{m}$) and nearby continuum ($2.26\mu\text{m}$) are also normally in the dewar. Five slots are available for other narrow-band or special purpose filters. Because QUIRC is kept cold, and only very infrequently opened, it may not be possible to accommodate special filter requirements. Any filter requirements other than the broad-band and common-use narrow-band filters listed above must be clearly listed on any proposal to use QUIRC, and communicated to support staff many months in advance. Transmission curves for the broad-band filters are shown in Fig. 7.12, and for selected narrow-band filters are shown in Fig. 7.13.

7.11 f/10 Faint Object Spectrograph (FOS)

This CCD spectrograph now replaces the old image tube Cassegrain spectrograph for long slit spectroscopy, providing spatial resolution of 0.49, 0.65 or 1.04 arcsec per $24\mu\text{m}$ pixel depending on camera, over a 4 arcmin field. The FOS employs coated transmission optics for both the collimators and cameras, where the latter are commercial Nikon, Canon or Zeiss lenses. Three collimators of focal length 400 mm are provided for peak transmission ($\geq 98\%$) in the blue (360–480 nm), visual (420–750 nm) or red (600–1000 nm) wavelength regions. Exchanging the collimator is a delicate procedure and should only be done by experienced observers during daytime.

There are 3 standard camera lenses of focal length 180 mm, providing peak transmission ($\geq 95\%$) in the blue, visual or red regions, which provide maximum spatial and spectral resolution. Two standard camera lenses of focal length 85 mm provide peak transmission in the visual and red regions, at lower resolution, but are rarely used now. A Zeiss lens of 135 mm focal length and good overall transmission provides the intermediate resolution option. Exchanging cameras should be avoided at night, as it requires two people to lower and support the CCD dewar, and will require refocusing of the spectrograph.

A range of standard (fixed) slits can be inserted in a 3 position slide mechanism at the focal plane, where the central position is kept clear for field viewing. Filters can also be inserted in one of the slide positions (at the focal plane) for imaging. A standard Fe-Ar hollow cathode comparison lamp can be remotely activated to illuminate the slit with an f/10 beam.

Spectrograph parameters are listed in Table 7.8.

The spectrograph beam size is 40 mm, and a range of reflection gratings listed in Table 7.9 provide reciprocal dispersions from 50 to 800 \AA mm^{-1} . Changing gratings and setting grating angles is done manually. A field viewing mirror on a slide adjacent to the grating can be remotely moved into the beam for field inspection or focal-reduced imaging. The spectrograph is generally used with the Tek 2048 CCD, providing the 2-pixel ($48\mu\text{m}$) resolution listed below, and an image area of 50 mm ($\sim 40\text{ mm}$ unvignetted image area).

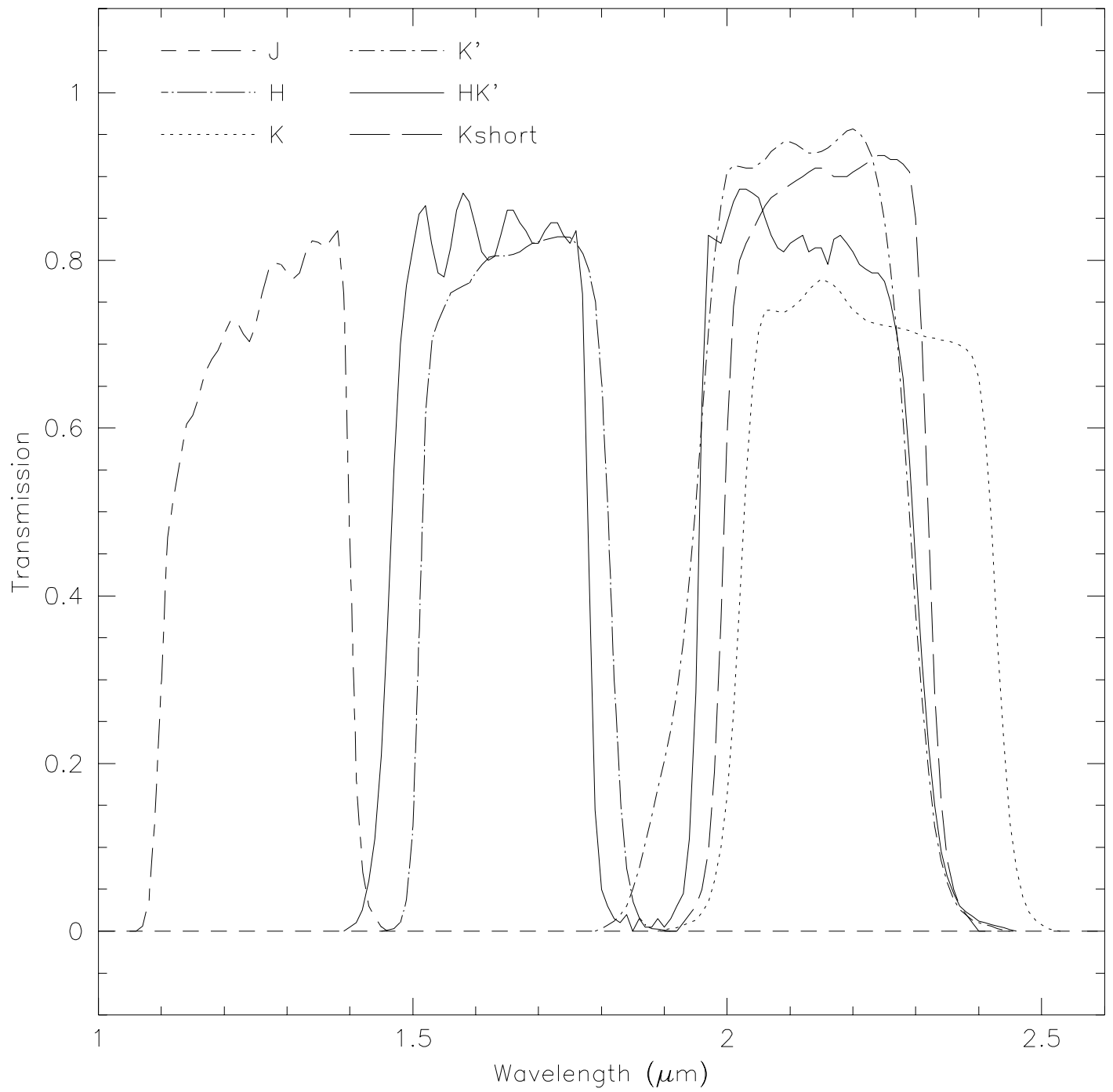


Figure 7.12: Transmission curves of broad-band infrared filters

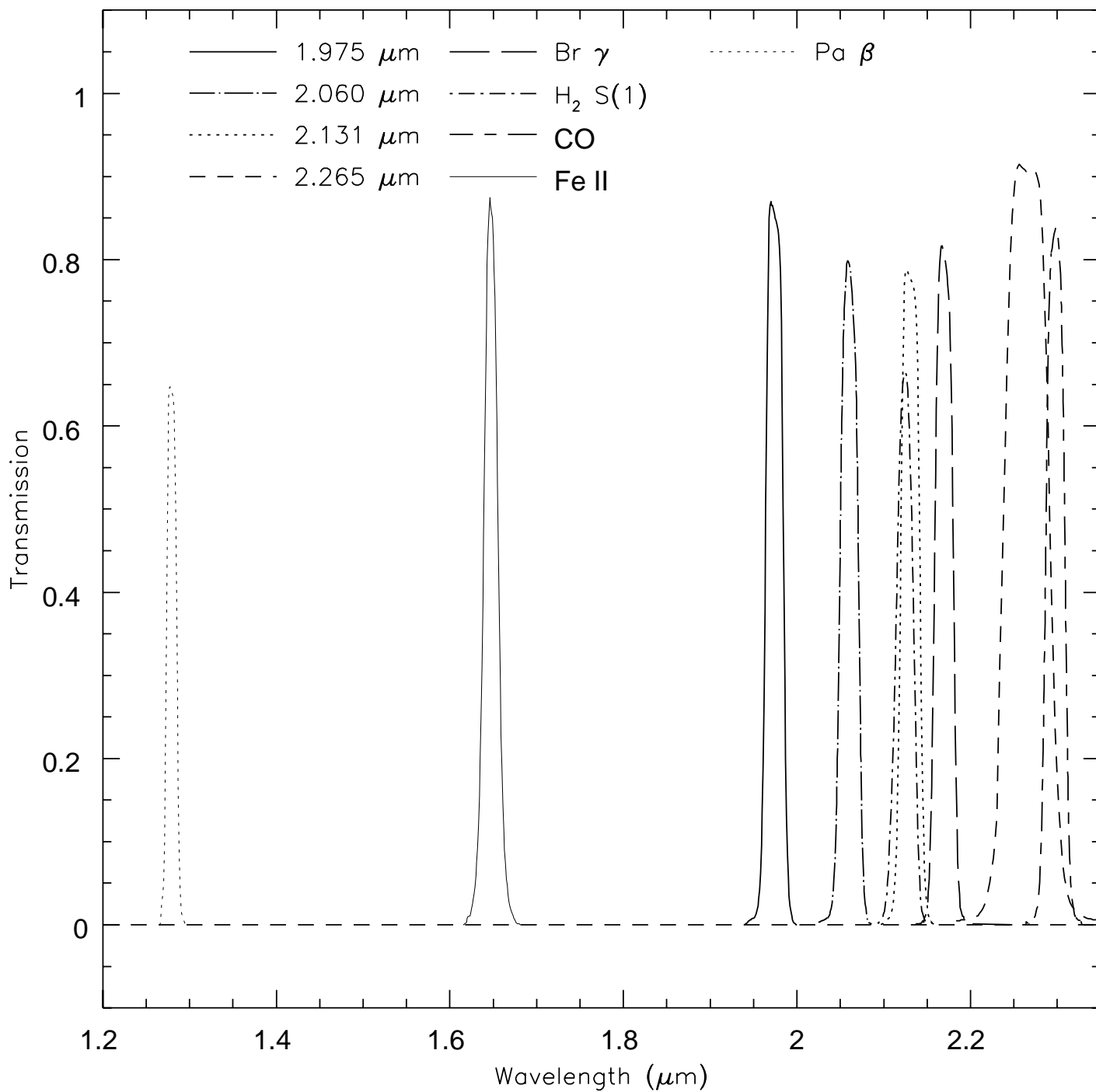


Figure 7.13: Transmission curves of narrow-band infrared filters

Table 7.8: Faint Object Spectrograph Characteristics

Collimators		400mm	blue, visual and red (marked)
Cameras	N180B	180mm	Nikkor ED f/2.8 424585 (blue: 360–480 nm)
	N180V	180mm	Nikkor ED f/2.8 387244 (visual: 420–780 nm)
	N180R	180mm	Nikkor ED f/2.8 412534 (red: 600–1000 nm)
	Z135	135mm	Zeiss f/2.0 5975158 (broad: 400–1000nm)
	C85V	85mm	Canon f/1.2 14427 (visual)
	Z85R	85mm	Zeiss f/1.2 6690245 (red)
Slits		$\mu\text{m} \times \text{mm}$	arcsec \times arcsec
		75×30	0.7×275
		140×30	1.3×275
		275×30	2.5×275
		514×26	4.7×240
		100×8	0.9×74
		160×8	1.5×74
		220×8	2.0×74
		720×8	6.6×74
Beam Size		40mm	
Field Size at Slit		26mm	4 arcmin
Image Scale at detector		180mm	$20.4 \text{ arcsec mm}^{-1}$; $0.49 \text{ arcsec}/24 \mu\text{m}$
		135mm	$27.2 \text{ arcsec mm}^{-1}$; $0.65 \text{ arcsec}/24 \mu\text{m}$
		85mm	$43.1 \text{ arcsec mm}^{-1}$; $1.04 \text{ arcsec}/24 \mu\text{m}$

Table 7.9: Faint Object Spectrograph Gratings

Grating (lines/mm)	Blaze \AA	Efficiency at blaze (%)	85mm camera		135mm camera		180mm camera	
			Dispersion $\text{\AA}/\text{mm}$	Resolution $\text{\AA}/48 \mu\text{m}$	Dispersion $\text{\AA}/\text{mm}$	Resolution $\text{\AA}/48 \mu\text{m}$	Dispersion $\text{\AA}/\text{mm}$	Resolution $\text{\AA}/48 \mu\text{m}$
150	8000	78	800	38	500	24	380	18
300	6400	87	400	19	250	12	190	9
500	7700	80	240	12	152	7	110	5.3
600	5000	85	200	10	126	6	95	4.5
600	10000	76	200	10	126	6	95	4.5
900	4500	81	133	6	84	4	75	3.6
1200	5000	82	100	5	63	3	50	2.4
1200	4000	80	100	5	63	3	50	2.4

Notes: All gratings are 52 mm square ruled area in 58 mm square blanks, mounted in holders.

Table 7.10: Wide Field Grism Spectrograph Characteristics

Collimator	210mm	visual (fixed)
Cameras	Z85V Z135	Zeiss f/1.4 Visual 6096959 Zeiss f/2 Visual 5975158
Slits	$\mu\text{m} \times \text{mm}$	arcsec \times arcsec
	120 \times 33	1.10 \times 303
	175 \times 33	1.60 \times 303
	200 \times 33	1.83 \times 303
	300 \times 33	2.75 \times 303
	419 \times 33	3.84 \times 303
	603 \times 33	5.53 \times 303
Beam Size	25mm	
Field Size at Slit	33mm	5 arcmin
Image Scale at detector	85mm	22.7 arcsec mm^{-1} ; 0.54 arcsec/24 μm
	135mm	14.3 arcsec mm^{-1} ; 0.34 arcsec/48 μm

Table 7.11: Wide Field Grism Spectrograph Dispersion Characteristics with Zeiss 135 mm lens

Groove/mm	Blaze \AA	Dispersion \AA mm^{-1}	Resolution with 120 μm slit	Coverage \AA
400	4800	148	11	7400
420	6400	141	11	7050
600	5000	100	8	5000
600	8500	100	8	5000

7.12 f/10 Wide Field Grism Spectrograph (WFGS)

The Wide Field Grism Spectrograph is a compact, all transmission system which can be attached to the ‘beam’ in front of a CCD, providing low dispersion spectroscopy. The collimator employs visual optics, and has a focal length of 210 mm, giving a collimated beam of 21 mm diameter. A range of cameras and standard slits is available, as listed in Table 7.10 below. A remotely operable slide in the collimated beam allows one of a range of grisms (listed in Table 7.11) to be inserted or removed. Another remotely operable focal plane slide gives a clear or aperture position.

The WFGS is generally used at f/6.5 with the Zeiss 135 mm lens, providing an image scale of 14.3 arcsec mm^{-1} , or 0.34 arcsec/24 μm pixel over a 5 arcmin field. The resolution listed in table 7.11 is limited by the projected slit width, and will decrease if wider slits are used.

7.13 f/31 High Angular Resolution Imaging Spectrograph (HARIS)

The f/31 High Angular Resolution and Imaging Spectrograph (HARIS) is an efficient and versatile two-camera spectrograph. It was built as part of an NSF research project by Dr. Alan Stockton at the IfA to take advantage of the excellent image quality of the University of Hawaii’s 2.2-m telescope and f/31 tip-tilt secondary (3 arcsec/mm scale, 4 arcmin field).

It can be used with the IfA’s CCD and NICMOS detectors for imaging and spectroscopy of faint and/or extended objects in the wavelength range 0.3–2.5 μm , at spectral resolutions in the range 300–7000, and angular resolution down to 0.3 arcsec.

Users can select one or both of two available camera ports. The long camera port (LFC) can support a CCD detector, at a detector image scale of f/10 (9.2 arcsec/mm). The short camera port (SFC) can support a CCD detector, usually at an image scale of f/4.5 (20.9 arcsec/mm). The spectrograph may thus be configured for two alternate or complementary observing modes, and rapidly switched between them at night (by switching the grating blaze).

Exchanging slits and filters, focusing cameras and tilting the grating to select wavelength may all be managed remotely via an X-window interface on a Unix workstation, communicating with a PC-BitBus controller. Exchanging gratings,

switching their blaze for use in the other camera port, and rotating the cassegrain rotator to obtain specific position angles must be done manually.

Slits are aligned N-S with the Cassegrain rotator in its standard (270deg) orientation. Slit Position Angles can be altered by at least 90 degrees either side of this to achieve any Sky PA however; the rotator setting appropriate to a desired slit PA can be found from the `tcsl` interface. Changing Position Angle must be done with the telescope at the Zenith, and necessitates recalibrating the offset guider; this process normally takes about 15 minutes.

Target objects must be carefully aligned on the (known) slit position by imaging either in the detector plane, or at a small below-slit Lynxx CCD. Since HARIS operates at f/31, targets may be either slow (telescope) guided, or fast-guided on the slit, and the Atlas guider can also be used to command small alignment offsets.

Calibration is currently achieved with flat-field and arc lamps attached to the telescope top-end ring, illuminating the dome. An internal system illuminating a retractable white screen in the telescope central baffle is planned.

7.13.1 HARIS schematic overview

Light from the f/31 focus of the UH 2.2-m telescope is focussed on the slit-plane of the spectrograph, which consists of a wheel with one open position, and provision for 4 fixed slits of different widths. Maximum slit length is 80 mm (4 arcmin at the f/31 telescope scale of 3 arcsec/mm), and this field is limited by coma increasing to 0.25 arcsec at 2 arcmin off-axis. The slits are tilted to allow for future slit-viewing capability.

Below the slit wheel and on a common shaft are 2 filter wheels, each containing one open position and provision for four 4-inch circular filters. The upper wheel is reserved for user filters, the lower for standard Cousins/Mould B, V, R, I filters.

A field-view mirror can be inserted below the filter wheels to feed a small Lynxx CCD-TV which can be used to view and align the target object at the slit position, and to check knife-edge (telescope) focus through a wide slit.

When this mirror is retracted, light proceeds to a fixed, aluminum-coated collimator of focal length 1253 mm, to form a 40 mm collimated beam. An alternate silver-coated collimator is planned for observations redwards of 4000 Å.

The collimator folds the beam back to a translation stage which moves to insert either a mirror (for focal reduced imaging) or grating into the beam. The mirror can be toggled between the two (LFC and SFC) camera port positions.

There are currently 14 gratings providing a range of resolutions at various blaze angles. All gratings can be (manually) inserted with blaze directed to either camera port.

The reflected or diffracted beam can be directed towards either the SFC or LFC transmission cameras, which refocus the light onto a CCD detector (SFC) or CCD or NICMOS detector (LFC).

Users have a choice of three 180 mm Nikon lenses for the SFC, coated for optimum performance in the Blue, Visual and Red wavelength regions respectively (these are the same as the f/10 FOS N180 camera lenses).

There are currently two custom-built 400 mm lenses for the LFC, optimized for use in the Visual-Red or Infra-red wavelength regions. Another LFC camera optimized for the UV is planned.

Schematic views of the f/31 spectrograph are shown in Figures 7.14 and 7.15.

7.13.2 Cameras, Collimators and Slits

The available optical and slit components for the f/31 spectrograph are summarized in Table 7.12 below.

7.13.3 Gratings and Resolution

The available gratings and the reciprocal dispersions they provide with LFC and SFC cameras are summarized in Table 7.13.

The wavelength coverage for the Tek2048 CCD (24 μ m pixels) and 256 \times 256 NICMOS detector (40 μ m pixels), together with the projected slit sizes corresponding to a slit width of 1 arcsec are also given.

Each grating is clearly marked with its grooves/mm, blaze wavelength and camera orientation, on both sides of the grating. When inspecting the grating through the grating access port, you should see SFC or LFC pointing towards the camera you are actually using. If not, insert the grating cover, unclamp and remove the grating, switch the cover to the alternate direction (taking care not to touch the grating surface), and reinsert and reclamp the grating.

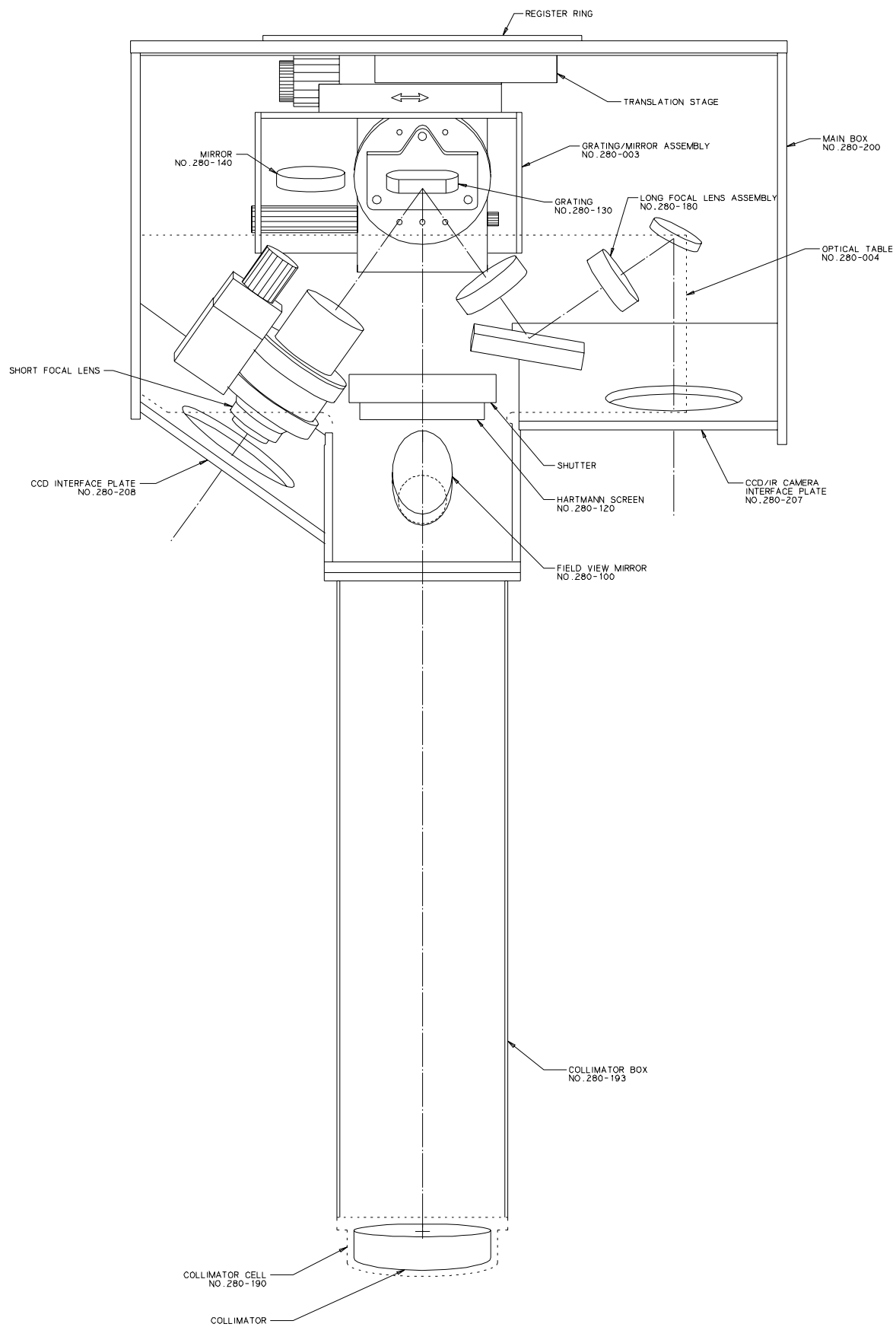


Figure 7.14: Front view of the f/31 HARIS spectrograph with the components and optical paths indicated.

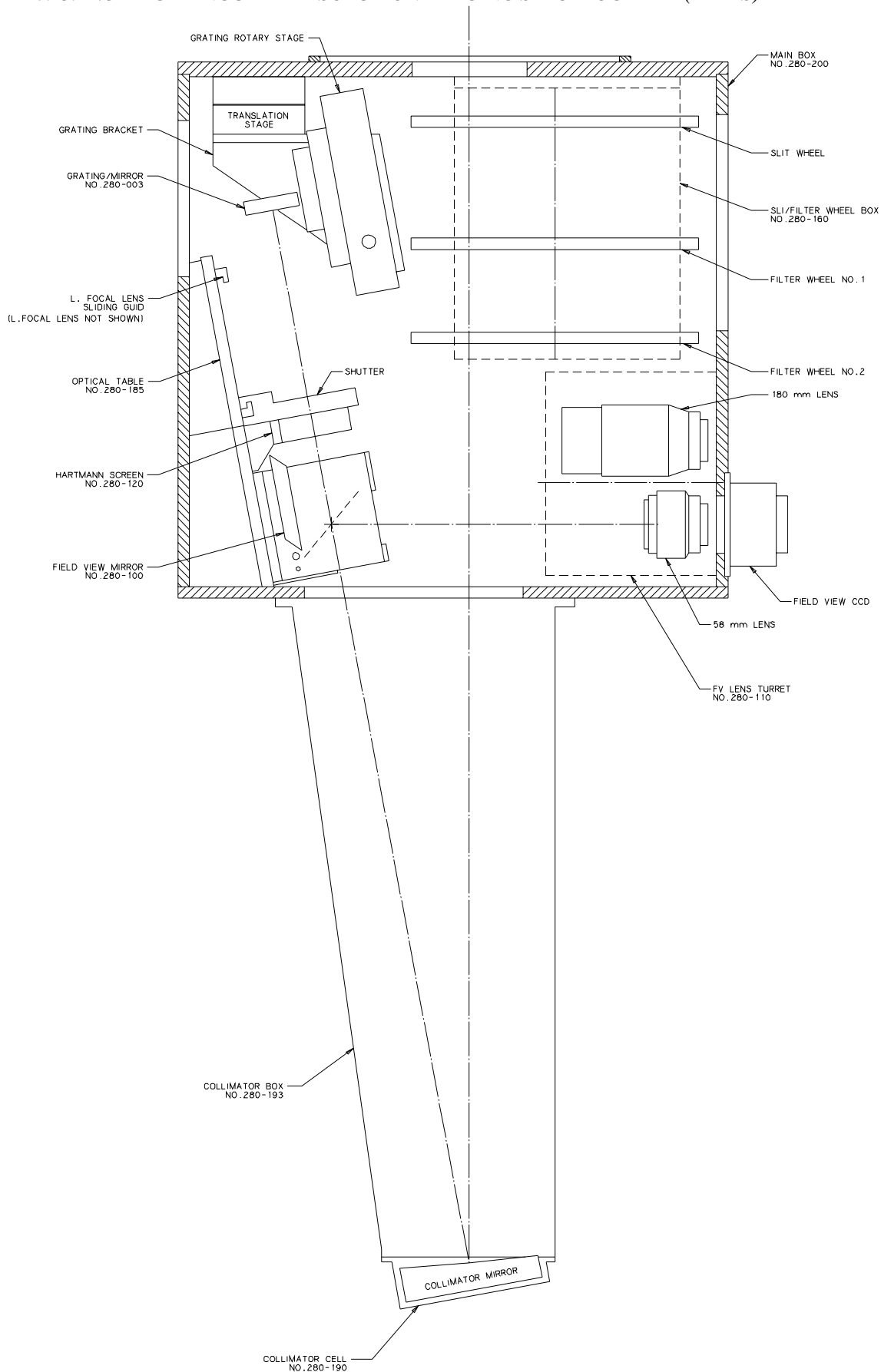


Figure 7.15: Side view of the f/31 HARIS spectrograph with the components and optical paths indicated.

7.13.4 Selecting Grating Tilt Angles

The Grating encoder has 450 counts/degree (8 arcsec/step), and is generally very repeatable provided it has been initialized correctly. The Grating Home position (after reset) is 18800 (tilted towards the LFC). The grating-horizontal setting is 26075.

At the moment, wavelengths are selected by entering grating rotary-stage encoder (GE) settings derived from the grating equation:

$$\lambda = \frac{2 \sin \beta \cos(17.5^\circ)}{10^{-7} n D} \quad \text{or} \quad (7.5)$$

$$\sin \beta = \frac{10^{-7} n D \lambda}{2 \cos(17.5^\circ)} \quad (7.6)$$

where λ is in Å, n is the order, D is grooves/mm, 17.5° is the camera-to-collimator semi-angle, and β is the dispersion angle. If i is the tilt angle (away from horizontal) measured towards the camera in use, and GE is the Grating Encoder setting, then

$$i = \beta + 17.5 \quad \text{and} \quad GE = 26075 \pm i \times 450 \quad (7.7)$$

Zero orders to short and long cameras ($\beta = 0.0$, $i = 17.5$) are:

33950 = 26075 + (17.5 × 450) (SFC – settings > 26075); and

18200 = 26075 – (17.5 × 450) (LFC – settings < 26075).

Grating Encoder settings for various gratings and selected wavelengths are listed in Table 7.14. Other settings can be interpolated from here.

7.14 f/31 JHK cross dispersed spectrograph—KSPEC

KSPEC utilizes a cross-dispersed echelle design to provide medium-resolution spectra of the 0.8–2.5 μm region, optimized for 2.2 μm . The instrument uses two arrays: a HAWAII 1024 × 1024 array is the detector for the spectral information; and a 256 × 256 NICMOS array is the slit-viewing array which images the region of the sky surrounding the slit. The control software runs on a Unix workstation and is similar to the QUIRC camera (see Section 7.10.1).

The imaging detector views the region of the sky surrounding the slit. The pixel scale is 0.24 arcsec/pixel; the field of view is approximately 1 arcmin square. Although the slit runs across most of this field, a mask permits only about 15 arcsec of the slit to pass to the spectrograph section. A K filter is permanently mounted in the imaging optics. The slit-viewing capability facilitates the source acquisition, centering, and guiding.

The spectrograph detector is a science-grade HAWAII device (1024 × 1024) with relatively few pixel defects in the regions used. For most pixels, the dark current is less than 0.1 e^-/sec and the read noise is about 12 e^- . The current device has pixels with high dark current near the bottom edge of the array. The spectrograph section is operated at 73K to reduce the dark current from these pixels and minimize their impact on the data. The pixel scale for the spectrograph detector is 0.167 arcsec/pix, and the usable slit length is approximately 17 arcsec.

Table 7.15 gives the approximate wavelength ranges and resolutions for the six orders. Sensitivity values are also given. These are 1σ values for a 3 minute on-source integration, after subtracting a similar 3 minute integration. *These sensitivity values may be incorrect, and are being reinvestigated.* If moving the source along the slit, then the total on-source time equals the total integration time and the numbers in Table 1 can be used to estimate this. If moving the object off the slit for sky frames (e.g., when observing an extended object), then the total integration time required will be two times the total on-source time. Figure 7.16 shows a spectrum of an A0 star on the spectral array, showing the six cross-dispersed orders.

Table 7.16 gives the resolution of each KSPEC slit, based on the measured resolution of slit #4 at the 2.2-meter telescope at 2.2 μm in the K order. The width of the slit on the spectrograph is about 3 Å wider than the physical size of the slit due to a slight defocus of the spectrograph optics. The defocus is different in each of the orders. For example, with slit #4 the resolutions in the orders are: 650 (K), 665 (H), 674 ($J2$), 585 ($J1$), and 571 ($I2$). Slit #4 is commonly used at the 2.2-m telescope. If your observations require a special slit, this must be clearly indicated on your proposal. The dewar must be warmed and opened to change the slit.

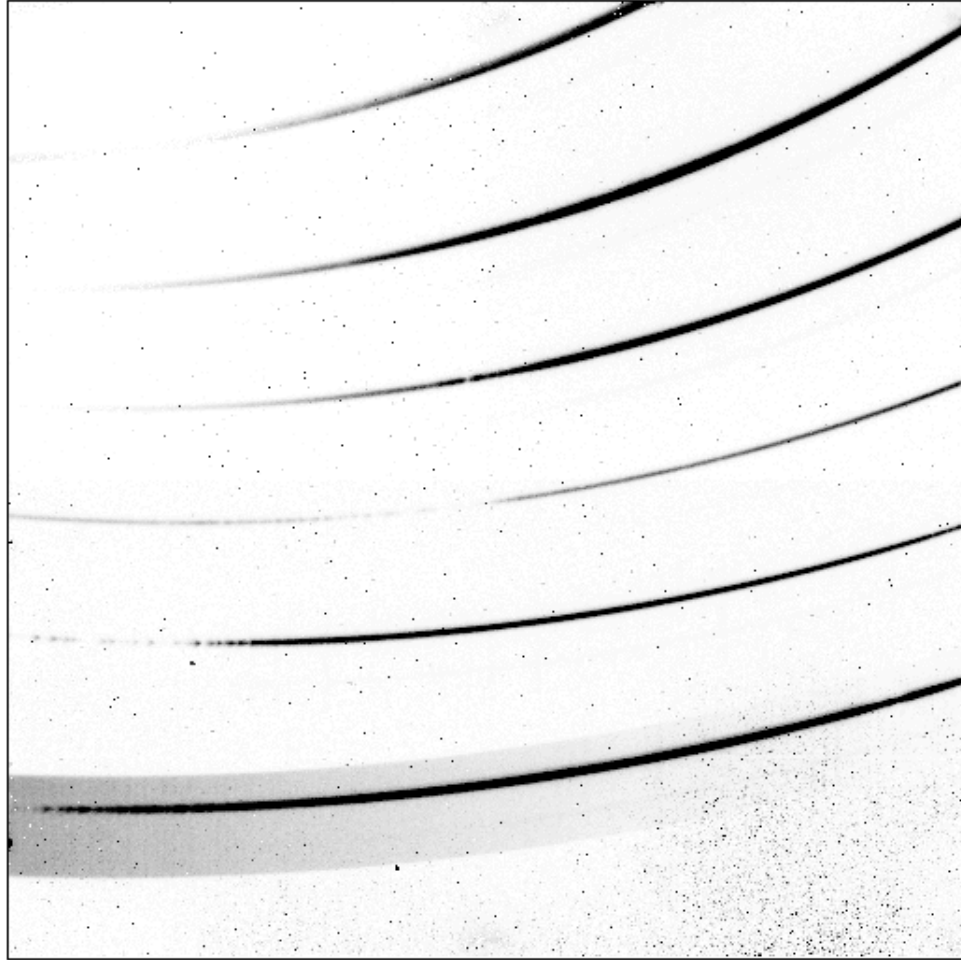


Figure 7.16: Spectral image of an A0 calibration star

7.15 Optical Photometer and Photon-Counting System

The Tinsley Photometer, which may be used on either the 61-cm or the 2.2-m telescope, is a self-contained system with an RCA C31034A GaAs photomultiplier, cooled by dry ice, and operating over a useful wavelength range of 300–900 nm. Quantum efficiencies vary from 38% at 300 nm to 18% at 900 nm. The photometer has a LeCroy MVL100 pulse amplifier/discriminator, and operates under the control of its own Apple II+ data system with custom counting electronics. The time constant is 124 ns.

The photometer is a standard, single beam Tinsley design accepting six apertures. Apertures presently available are listed in Table 7.17; new apertures may be made by visiting observers prior to arrival if needed.

There is an internal six position filter wheel which is no longer used however. Observations are now made with an eight position filter wheel sandwiched between the photometer top section and the cold box. Access is via a slide-off cover at the rear of the octagonal filter wheel. The wheel is designed to hold 2 in square filter holders, 12 mm thick, and about 2 dozen of these filter holders are available. Several of these are used for asteroid and comet filter sets, and are ‘permanently’ labeled and should not be disturbed. Several other filter holders are available for other users of the photometer.

7.16 2.2-m Coudé f/34 Spectrograph

The spectrograph is arranged in the classical manner, with the axis of the slit-to-collimator beam a continuation of the polar axis of the telescope. The f/33.6 collimator is an off-axis paraboloid which produces a beam of 20 cm diameter from a point source. The cameras are on-axis Schmidt systems, which are selected by rotating the grating to the proper angle and, by using a rotating turret or “spit”, bringing the proper camera into the beam from the grating. An overhead trolley arrangement facilitates moving gratings from a storage rack to the mounting turntable; changing gratings requires about 5 min.

The spectrograph is supported by a frame of heavy steel beams which is horizontal in the east-west direction and inclined at an angle equal to the latitude in the north-south direction. The north end of the spectrograph frame rests on the telescope pier, while the south end is supported by members which rest on separate piers, also isolated from the building. The temperature in the spectrograph room is not controlled, but is allowed to “float” in response to seasonal variations. The high thermal inertia minimizes diurnal variations.

7.16.1 Coudé Slit Instrumentation

The stainless-steel biparting slit jaws are controlled by a micrometer which provides an indication of the separation to 0.001 mm. The maximum slit width is 2.0 mm. The slit length is limited by a V-shaped dekker which can be adjusted continuously to a maximum length of 50 mm. A 30×30 mm quartz prism is mounted on a vertical slide below the slit jaws. When this is moved up (manually), it blocks the starlight, and folds light from one of 3 sources to the right-hand side into the spectrograph beam.

7.16.2 Comparison Sources

Light from any one of three comparison sources may be selected by a rotatable prism. The three sources are currently: 1) Halogen white light (for flat-fields), 2) Thorium-Argon arc lamp and 3) Neon arc lamp.

7.16.3 Filter Mounting

A slide for a 50 mm square filter is provided behind the slit. In this position, both the stellar and comparison beams are affected. An arrangement to mount a filter ahead of the slit, in the stellar beam only, is also available.

7.16.4 Coudé Cameras

Observations can currently be taken with the Tek 2048 CCD (24 μ m pixels) or Orbit 2048 CCD (15 μ m pixels), which can be mounted at cameras number 1, 3, and 4 only. Focusing the CCD is achieved manually on camera 1, and remotely by *bitbus* control on cameras 3 and 4.

The coudé spectrograph design includes five cameras of focal lengths increasing by factors of two from 0.3 m to 4.9 m (1 to 16 ft); the significant numerical parameters of those cameras are given in Table 7.18. All cameras are of

classical Schmidt design, with single-pass correcting plates (except camera 1 which does not require a corrector) and folding (on-axis) pickoff mirrors directing light to a CCD arranged orthogonally out of the beam.

The two shortest cameras each have a choice of two correcting plates—one of fused quartz for wavelengths shorter than about 450 nm, and another of BSC-2 glass for wavelengths longer than about 400 nm. Camera No. 1 does not require a correcting plate.

Dispersions listed in Table 7.18 are for a grating of 600 lines/mm used in the second order, and the exposure data are for this dispersion used to expose the Tex 2048 CCD to give a spectrum 0.5 mm wide with a projected slit width of 0.048 mm. The limiting V magnitude is for S/N=100 in a 1 hr exposure. The data are based on experience under good but not exceptional seeing conditions, with no cloudiness.

7.16.5 Coudé Gratings

The characteristics of the gratings are listed in Table 7.20. All are 20×25 cm (8×10 in) ruled area, single-diamond gratings, with blaze efficiencies near 50%. Since the blaze wavelength is affected by the spectrograph geometry, slightly different blaze wavelengths are obtained for the 16 ft (No. 1) camera than for all the shorter cameras, and both are given. Reciprocal dispersions for the gratings used in their useful orders are given in Table 7.20.

7.16.6 Grating Angle

This is set by unlocking the grating turntable, moving the grating manually to the approximate grating angle (read from an illuminated display in the spectrograph room itself), then fine-tuning the setting (to 0.01 degree) by carefully adjusting the gear mechanism below the grating turntable. Grating angles can be determined from the grating equation adjusted for the camera-to-collimator semi-angle ($s/2 = 5.6^\circ$ camera 1, $s/2 = 15.5^\circ$ cameras 2–5) appropriately:

The Grating Angle i in degrees (including a small zero point) is given by:

$$i = \beta + s/2 - 0.1^\circ \quad (7.8)$$

where

$$\sin \beta = \frac{10^{-7} n D \lambda}{2 \cos(s/2)} \quad (7.9)$$

and n is the grating order, D is number of lines/mm for the grating, and λ is the wavelength in Å. Examples of grating angles are given in Table 7.19.

Users should switch all lights off in the coudé spectrograph and wait a few minutes for their eyes to adjust to check for any light leaks or dim sources before observing.

Do NOT use the fluorescent lights in the coudé spectrograph before or during coudé observing, as these cause the wall paint to fluoresce dimly.

Use telescope oil-pump number 2 (ground floor) to minimize spectrograph vibration during coudé observing.

Table 7.12: f/31 HARIS Spectrograph Components

Collimator		1253mm	Aluminum coated
SFC cameras	N180B	180mm	Nikkor ED f/2.8 424585 (blue: 360–480 nm)
	N180V	180mm	Nikkor ED f/2.8 387244 (visual: 420–780 nm)
	N180R	180mm	Nikkor ED f/2.8 412534 (red: 600–1000nm)
LFC cameras	400VR	400mm	visual-red 370–1000nm
	400IR	400mm	infra-red 1-2.5 μm
Slits		$\mu\text{m} \times \text{mm}$	arcsec \times arcsec
		170 \times 75	0.51 \times 225 ²
		237 \times 80	0.71 \times 240
		355 \times 75	1.07 \times 225 ²
		530 \times 80	1.59 \times 240
		695 \times 80	2.1 \times 240
		992 \times 80	3.0 \times 240
		1420 \times 75	4.3 \times 225 ¹

Notes:

¹ Old slit made with blades; other slits are precision machined.

² Slits machined from thinner material, shimmed to same height (focus) as other machined slits.

Table 7.13: f/31 HARIS Spectrograph Gratings and Dispersions

Grating Ref. No.	Grating Pitch groove/mm	Blaze Wavelength \AA	SFC ¹ 180mm Camera		LFC ² 400mm Camera	
			Dispersion $\text{\AA}/\text{mm}$	1-arcsec Slit Proj. μm	Dispersion $\text{\AA}/\text{mm}$	0.5-arcsec Slit Proj. μm
1	300	4200	178	48	80	53
2	300	5000	179	48	80	53
3	300	6400	180	48	81	53
4	300	17000	179	48	80	53
5	600	4000	90	47	41	53
6	600	5000	91	47	41	53
7	600	6500	92	47	41	52
8	600	7500	92	46	41	51
9	1200	4000	46	46	21	51
10	1200	5000	46	45	21	50
11	1200	6000	46	44	21	49
12	1200	7500	46	42	21	46
13	1800	5000	31	42	14	46
14	86	9600	642	48	289	53

Notes:

⁰ Resolution and sampling information assumes a CCD with 24 μm pixel size. For the Tek2048 CCD, wavelength coverage is Dispersion multiplied by 50mm. The same coverage and resolution can often be obtained with either camera. The SFC will use a wider slit (more light and less spatial sampling). The LFC requires a narrower slit, provides more spatial sampling, and can reach the highest resolutions.

¹ The SFC provides slit-limited resolution (2-pixel projected slit) with a 1-arcsec slit. Wavelength resolutions are 8.6, 4.3, 2.0 and 1.3 \AA with the 300, 600, 1200 and 1800 line/mm gratings respectively and a 1-arcsec slit. The spatial sampling is 0.51 arcsec per 24 μm pixel with the 180mm SFC.

² The LFC provides slit-limited resolution (2-pixel projected slit) with a 0.5 arcsec slit. Wavelength resolutions are 4.2, 2.1, 1.05 and 0.66 \AA with the 300, 600, 1200 and 1800 line/mm gratings respectively and a 0.5-arcsec slit. The spatial sampling is 0.23 arcsec per 24 μm pixel with the LFC.

Table 7.14: f/31 HARIS Spectrograph Grating Settings

				26075	
				−450×tilt	+450×tilt
Grating No.	l/mm	Wavelength Å	Tilt Angle Degrees	Grating Encoder	
				LFC	SFC
1–3	300	4000	21.11	16575	35575
		5000	22.01	16175	35980
		6000	22.91	15765	36385
		7000	23.82	15355	36795
		8000	24.73	14950	37205
		9000	25.64	14540	37615
4	300	12500 <i>J</i>	28.84	13100	
		16000 <i>H</i>	32.07	11645	
		22000 <i>K</i>	37.74	9090	
5–8	600	4000	24.73	14950	37200
		5000	26.55	14130	38020
		6000	28.38	13305	38845
		7000	30.22	12475	39675
		8000	32.07	11640	40510
		9000	33.95	10800	41350
9–12	1200	4000	32.07	11645	40505
		5000	35.83	9950	42200
		6000	39.68	8220	43930
		7000	43.63	6440	45710
		8000	47.72	4600	47550
		9000	51.99	2680	49470
13	1800	4000	39.68	8220	43930
		5000	45.65	5530	46620
		6000	51.99	2680	49470
14		9000	19.83	17155	34995
		1μm	20.08	17040	35111

Table 7.15: KSPEC Orders (0.96'' slit, 2.2-m telescope, 3 min exposure)

Order Name	Range (μm)	Scale (μm pixel ^{−1})	Continuum (10 ^{−14} W m ^{−2} μm ^{−1})	Sensitivity	
				Mag.	Line Flux (10 ^{−16} W m ^{−2})
<i>I1</i>	0.81–0.95	.00014
<i>I2</i>	0.84–1.08	.00022	11.0	...	43
<i>J1</i>	0.98–1.27	.00029	9.5	...	12
<i>J2</i>	1.18–1.52	.00034	9.6	11.1	22
<i>H</i>	1.47–1.90	.00042	2.7	11.4	1.8
<i>K</i>	1.96–2.54	.00056	0.94	11.5	3.1

Table 7.16: Available Slits for KSPEC

Slit #	Slit widths		Resolution (K order) ($\lambda/\Delta\lambda$)
	2.2-meter (arcsec)	CFHT (arcsec)	
1	0.33	0.19	1570
2	0.56	0.32	1030
3	0.79	0.45	760
4	0.96	0.56	650
5	1.08	0.62	570
6	1.47	0.85	430
7	1.65	0.95	390
8	1.92	1.10	335
9	2.11	1.22	310
10	2.61	1.50	250

Table 7.17: Optical photometer apertures

Aperture Number	Diameter in mm	Diameter at 61-cm f/15 (arcsec)	Diameter at 2.2-m f/10 (arcsec)
1	0.12	2.6	1.1
2	0.36	8	3.3
3	0.73	16	6.5
4	1.04	22	9.5
5	1.29	28	12
6	1.48	32	14
7	2.0	43	18
8	2.54	54	23
9†	3.65	78	33

Note: † presently blanked off.

Table 7.18: Coudé Spectrograph Characteristics

Characteristic	Camera Number				
	1	2	3	4	5
Focal Length (cm)	487	243	122	60.9	30.5
Focal Length (ft)	16.0	8.0	4.0	2.0	1.0
Camera to Collimator (degrees)	11.2	31.0	31.0	31.0	31.0
Reduction factor (slit to detector)	1.38	2.75	5.50	11.0	22.0
Minimum Slit Width ¹ (μm)	41	83	165	330	660
Minimum Slit Width ¹ (arcsec)	0.11	0.23	0.45	0.90	1.80
Maximum Resolution ²	93000	44400	22700	11300	5700
Dispersion ³ ($\text{\AA}/\text{mm}$)	1.68	3.42	6.84	13.6	23.0
15 μm pixel in \AA	0.025	0.05	0.10	0.20	0.40
15 μm pixel in arcsec	0.08	0.15	0.30	0.61	1.21
Σ Photons/pixel/sec ⁴ ($V=5, \epsilon=15\%$)	150		2500	10,000	
Limiting Vmag, S/N=100 in 1 hr	9		12.5	13.5	

Notes:

¹ For a projected slit width of 30 μm at the detector; this should be increased linearly for larger pixels.

² Maximum attainable for typical 2nd order grating angles at 5500 \AA and minimum slit width; this should be decreased linearly for larger pixels.

³ For a 600 line grating in 2nd order.

⁴ For a star $V=5\text{mag}$, overall optical efficiency $\epsilon = 15\%$, summed along the slit, minimum slit width and seeing ~ 1 arcsec. Larger pixels (X) increase this factor by $(X/15)^2$ (wider slit, more wavelength per pixel).

Table 7.19: Examples of Coudé Grating Angles

Camera	n	D	λ	i
1	2	600	6965	30.33
3/4	2	600	6965	41.10
1	2	900	4158	27.59

Table 7.20: Coudé Spectrograph Gratings and Dispersions

Characteristic	Grating Number			
	1A	2A	3A	4A
Lines/mm	600	600	400	900
Blaze Angle (degrees)	14.7	24.0	14.7	24.0
Blaze λ 1st order, No. 1	0.84 μm	1.35 μm	1.25 μm	0.91 μm
Nos. 2–5	0.81 μm	1.32 μm	1.22 μm	0.88 μm

Grating	Order	Blaze ¹ (\AA)	Dispersions in $\text{\AA}/\text{mm}$ for Camera				
			1	2	3	4	5
1A 600 l/mm	1 IR	8100	3.36	6.72	13.44	26.9	53.8
	2 Blue	4050	1.68	3.36	6.72	13.44	26.9
2A 600 l/mm	1 IR	13200	3.36	6.72	13.44	26.9	53.8
	2 Red	6600	1.68	3.36	6.72	13.44	26.9
	3 Blue	4400	1.12	2.24	4.48	8.96	17.92
	4 UV	3300	0.84	1.68	3.36	6.72	13.44
3A 400 l/mm	1 IR	12200	5.04	10.08	20.16	40.32	80.64
	2 Red	6100	2.52	5.04	10.08	20.16	40.32
	3 Blue	4070	1.68	3.36	6.72	13.44	26.9
	4 UV	3050	1.26	2.52	5.04	10.08	20.16
4A 900 l/mm	1 IR	8800	2.24	4.48	8.96	17.92	35.84
	2 Blue	4400	1.12	2.24	4.48	8.96	17.92
	3 UV	2930	0.75	1.49	2.99	5.97	11.95

Notes:

¹ Blaze wavelength applies to cameras 2–5, slightly longer wavelengths apply to camera 1 (see above).

Appendix A

Names and Addresses

A.1 Institute for Astronomy (Honolulu) Staff

Honolulu Address:	Institute for Astronomy University of Hawaii 2680 Woodlawn Drive Honolulu, HI 96822, U.S.A. Tel: (808) 956-8312 Fax: (808) 956-9590
Director:	Dr. Donald N.B. Hall (director@ifa.hawaii.edu) Tel: (808) 956-8566 Fax: (808) 946-3467
Director of UH Telescopes:	Dr. Lennox L. Cowie (cowie@ifa.hawaii.edu) Tel: (808) 956-8134 Fax: (808) 946-3467
Support Scientist:	Dr. Richard J. Wainscoat (rjw@ifa.hawaii.edu) Tel: (808) 956-6756 Fax: (808) 956-9590

A.2 Institute for Astronomy (Hilo and Summit Staff)

Hilo Address: Institute for Astronomy
1175 Manono St.
Building 393
Hilo, HI 96720, U.S.A.
Tel: (808) 974-4205
Fax: (808) 974-4207

Hilo Postal address: Institute for Astronomy
P.O. Box 4729
Hilo, HI 96720, U.S.A.

Support Scientist: Dr. Andrew J. Pickles (pickles@ifa.hawaii.edu)
Tel: (808) 974-4205
Fax: (808) 974-4207

Telescope Superintendent: Mr. Kenneth Maesato (maesato@ifa.hawaii.edu)
Summit: (808) 974-4200
Summit fax: (808) 974-4202

Telescope Foreman: Mr. Melvin Inouye (inouye@ifa.hawaii.edu)
Summit: (808) 974-4200
Summit fax: (808) 974-4202

88-inch Telescope: Tel: (808) 974-4200
Fax: (808) 974-4202

Hale Pohaku 2.2-m office: Tel: (808) 974-4204

A.3 Mauna Kea Support Services

Hilo Address: MKSS
177 Makaala St.
Hilo, HI 96720 U.S.A.
Tel: (808) 935-3371

Manager: Mr. Ron Koehler (koehler@ifa.hawaii.edu)

Hilo: Ms. Gail Forbes (forbes@ifa.hawaii.edu)

Hale Pohaku: Mr. Jimmy Nojiri (nojiri@ifa.hawaii.edu)
Tel: (808) 935-7606
Fax: (808) 969-7624

Road Conditions: Tel: (808) 969-3218 (recorded message)

A.4 Airport—General Lyman Field, Hilo HI 96720

National and International

Continental Airlines: 1-800-525-0280
Northwest Airlines: 1-800-225-2525
United Airlines: (808)-961-2811
American Airlines: 1-800-433-7300

Inter-island Flight Reservations

Aloha Airlines:	Hilo:	(808) 935-5771
	Honolulu:	(808) 484-1111
	U.S. Mainland	1-800-367-5250
	Tokyo	(03) 3216-5877
	Osaka	(06) 341-7241
Hawaiian Airlines:	Canada	1-800-235-0936
	Hilo:	(808) 326-5615
	Honolulu:	(808) 838-1555
	U.S. Mainland	1-800-367-5320
	Canada	1-800-367-5320

A.5 Hilo-based Trucking Firms

Yamada Transfer	Kuwaye Trucking Inc.
733 Kanoiehua Avenue	2055 Kamehameha Avenue
Hilo, HI 96720	Hilo, HI 96720
(808) 933-8400	(808) 935-2845
	Fax: (808) 935-4045

A.6 Customs

Local Customs Brokerage Firm (others are available):

Skelton-Kohara and Co. Ltd.
 736 South St., Room 201
 Honolulu, HI 96813
 Tel: (808) 524-2663
 Fax: (808) 533-7097

Other information:

District Director of Customs
 335 Merchant Street, Room 225
 Honolulu, HI 96813, U.S.A.
 Tel: (808) 522-8400

A.7 4-wheel Drive Vehicle Rentals—Big Island

At the time of writing, there was only one company which rents 4-wheel drive vehicles, and permits them to be driven on the saddle road:

Rental Company	Approximate Cost	Comments
Harper Car and Truck Rental 1690 Kamehameha Avenue Hilo, HI 96720 (808) 969-1478 Fax: (808) 961-0423		Permitted on Saddle Road
Isuzu Trooper II	\$85.95/day + tax	Free pick-up and delivery from Hilo hotels and airport Credit card required for reservation

A.8 Accommodation in Hilo

Hilo Bay Hotel 87 Banyan Drive Hilo, HI 96720 (808) 935-0861	Hilo Hawaiian Hotel 71 Banyan Drive Hilo, HI 96720 (808) 935-9361	Hilo Hotel 142 Kinoole St. Hilo, HI 96720 (808) 961-3733
Hilo Seaside 126 Banyan Way Hilo, HI 96720 (808) 935-0821	Hawaii Naniloa Hotel 93 Banyan Drive Hilo, HI 96720 (808) 969-3333 1-800-442-5845 (HI) 1-800-367-5360 (US)	Waiakea Resort Village 400 Hualani St. Hilo, HI 96720 (808) 961-2841 Fax: (808)-961-6797

Appendix B

Forms

B.1 Observing Time Request Form

The observing time request form may be found on the following pages. Applicants must fill in pages 1–5 completely.

The scientific justification for the observing time request should follow, and is limited to 5 pages of text and 2 pages of figures. References do not count against these page limits. Proposals that exceed these limits will not be accepted.

University of Hawaii • Institute for Astronomy
Research Proposal—Observing Time Request

PI Name:	Proposal Number:
PI Institution:	
PI E-mail:	Semester: 1 Year: 1998
PI Phone:	PI Fax:

PROGRAM TITLE(S) <i>(one line per program)</i>
A.
B.
C.
D.
E.

ABSTRACT(S) <i>(one single abstract or one abstract per program)</i>

TELESCOPE TIME REQUESTED

Run	Program	Telescope	Focus	Instrument	Nights	Lunar Phase	Observers' Initials
1							
2							
3							
4							
5							
6							
7							
8							
9							

Run	Optimum Dates	Acceptable Dates	Unacceptable Dates (Give reasons)
1			
2			
3			
4			
5			
6			
7			
8			
9			

COLLABORATORS

Name	Institution	E-mail	Program(s)

TELESCOPE TIME AWARDED TO PI IN THE LAST 2 YEARS

Include upcoming awarded time. Give date, number of nights, telescope, instrument, program title, and briefly list status, results, and publications. Use an additional page if necessary.

Is this proposal part of an approved thesis program? *If yes, list ALL telescope time awarded for the thesis above, and summarize the total amounts of time here:*

LIST OF PUBLICATIONS OF THE PI OVER THE PAST 2 YEARS

Include only refereed and invited papers published or in press within two years prior to due date of application. List facilities used for each paper.

SCIENTIFIC JUSTIFICATION(S)

*On the following pages, give the scientific justification for your program(s). Use any format you choose (e.g., an integrated discussion of closely related programs, separate discussions for each program, or a general introduction with separate detailed discussions). The scientific justification has a **total** limit of 5 pages of text, 2 pages of figures or tables, plus references (no limit). You may embed figures and tables in the text, and you may substitute figures or tables for text, but not vice versa. Use no less than an 11-point font and half-inch margins. Proposals that exceed these limits will be returned to the submitter.*

TECHNICAL JUSTIFICATION

Discuss the feasibility of the observations and justify the amount of telescope time requested. The technical justification is limited to one-half page per run. Use an additional page for each run.

Run No:	Telescope:	Instrumentation:
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LIST OF PRINCIPAL OBJECTS *(to be studied in run justified above)*

Program	Object	RA (h,m)	Dec (deg)	Mag (specify band)

B.2 Observer's Report

University of Hawaii Telescopes on Mauna Kea

OBSERVER'S REPORT

This form provides you with a channel to comment on any problems associated with your observing run, to compare the facilities provided with your expectations or other telescope experience, and to offer constructive suggestions for future improvements. Please complete by the end of your run, and hand in to the telescope operator.

- 1) Observer(s):
- 2) Telescope Operator/Telescope:
- 3) Brief Program Title:
- 4) Observing dates:
- 5) Instrumentation used:
- 6) Total possible observing hours:
- 7) Estimated time lost in hours due to:

Weather	Telescope	Instrument	Detector	Computers	Other (please specify)

- 8) Please comment on any relevant aspect of your run, such as: quality of data obtained; telescope serviceability and operation; instrumentation and detectors; object acquisition and guiding; data collection and presentation; documentation.

- 9) Please identify the single item or area which you think would most benefit from attention, rectification, or creation (continue overleaf if necessary).

Appendix C

Mauna Kea Support Services

C.1 Lodging Service

1. Lodging is provided in three buildings, B, C & D, which have a total of 72 rooms. Reservations are made by the sponsoring organizations to the MKSS Administration. Buildings B, D, and half of C are non-smoking. Reservations should include preferences for non-smoking/smoking rooms, along with any special meal requirements (e.g. vegetarian).
2. All guests should register at time of arrival at Hale Pohaku.
3. Two keys are assigned per room. One key is for the room door and the other is for the outside door. To lock your room when you leave, you must use the key. Please return keys when checking out. *If you do not return your key when you leave Hale Pohaku, you will be charged for additional nights' accommodation.*
4. Cold weather clothing is available for guests' use. Parkas and coveralls are available. A nominal rental fee is charged to cover cost of cleaning and repair.
5. Electronic alarm clocks are installed in each room.
6. Personal laundry service is available for long term guests at Hale Pohaku. Please coordinate your requirements with the front desk. Each washer load consumes about forty gallons of water and should be efficiently used.
7. Clean linen is provided on a four day basis. Additional towels are available on request.
8. General cleaning of rooms is also on a four day basis; however, additional cleaning will be done on request.
9. Room assignments are made on an "as available" basis. If there are special requirements for rooms, please make them known in advance of arrival.
10. Pillows for the bed are located in the drawers beneath the bed.
11. Personal items (cigarettes, toothpaste, etc.) are not available and sufficient supplies should be brought with you for the length of your stay. Soap and shampoo are provided.
12. **Check-In:** Please make known your approximate check-in time when your reservation is made. When you enter through the main door, your key and a document describing your reservation are on the counter on the left. Check and sign the registration document—if there is an error, please note it on the form, and inform your sponsoring agency. A map is available at the check-in desk which shows the layout of Hale Pohaku, and can be used to locate your room. There is a key to the main door at Hale Pohaku on the vehicle keyring. It is marked "HP."
13. **Check-out:** To check out, simply place keys in the deposit box located on the front desk. Check-out time is 2:00 p.m. If you need your room later than 2:00 p.m., please ask the manager whether this is possible. If you have not checked out by 2:00 p.m. on your day of departure (and have not made arrangements for late check-out), you will be charged for another day, because the room cannot then be made ready for another guest. If you are departing Hale Pohaku late in the day, your luggage can be stored. Please see the manager. It is very important that you remember to leave your keys in the check-out box before you leave HP. Please check carefully—if you forget to leave your key, you will be charged for an extra day of accommodation.

Room and meals (per day)	\$70
Breakfast	\$6
Brunch/Snack	\$2
Lunch	\$8
Summit lunch	\$9
Dinner	\$13

14. **Charges:** Residents at Hale Pohaku are charged a flat rate which includes accommodation and meals. Meals consumed before 2:00 p.m. on the check-in day or after 2:00 p.m. on the check-out day are charged at the meals only rate. Non-residents are charged for meals consumed. All billing is done through the sponsoring agency (for the 2.2-meter telescope, billing is done through the University of Hawaii). The costs for accommodation and meals, effective January 1, 1996, and subject to change without notice, are:

C.2 Library

A library is located on the second level of the main building for your use. It is equipped with a Sky Atlas, Polaroid camera, photocopier, workstation with CD-ROM drive for access to electronic catalogs, electric typewriter, technical and professional books, journals, and other publications.

C.3 Offices

Offices are located on the second floor of the main building as follows: CFHT—Rooms 200 to 201; Keck—Room 202; CSO—Room 203; UKIRT—Room 204; UH 2.2-meter—Room 205; IRTF—Rooms 206 and 207. Keys and usage of these offices are controlled by User Organizations.

C.4 Locker Services

Assignment of lockers is done by the User Organizations.

C.5 Mail Service

Incoming and outgoing mail service is provided daily, Monday–Friday. The incoming mail address is:

NAME
Hale Pohaku
177 Makaala Street
Hilo, Hawaii 96720

C.6 Telephone Service

Telephones are available at the front desk, and can be made available in your room on request. However, only local calls can be made with these phones. Toll calls must be made from the phones in the user organization offices.

Local and interisland calls can be made from the 2.2-meter office, but interstate and international calls are blocked. Be sure to bring a telephone credit card if you wish to make these long-distance calls. Telephone credit card calls can only be made by dialing a 1-800 access number (e.g., 1-800-CALL-ATT for AT&T).

C.7 Water, Electricity and Heat

Water and energy are expensive at Hale Pohaku. Water and fuel must be hauled from Hilo (58 km) and transport charges are high. Electricity is provided by HELCO. Please make every effort to conserve water and energy.

C.7.1 Vehicle Gasoline

Gasoline is available at the maintenance facility for authorized users. The key for gas pump is located at the front desk, attached to a clipboard. An honor system is employed—fill in the amount of gasoline taken on the sheet on the clipboard. Also on the clipboard is a key for water faucet at the gas pump island in case the windshield needs cleaning. Please conserve water.

C.7.2 Fire

Fire is always a hazard, especially at Hale Pohaku, which is 58 km (36 miles) from a fire station. If you must smoke, do so awake and in a vertical position.

C.7.3 Food Service

1. All meals are served buffet style with the exception of night lunches.
2. A weekly menu is displayed on the bulletin board opposite the elevator. We will try to accommodate guests with special dietary requirements—please provide adequate notice.

3. Meal Hours:

Hale Pohaku

Breakfast	06:00–08:00	
Lunch	12:00–13:00	(Breakfast orders available)
Dinner	16:30–18:30	

Summit

Lunch	11:30–12:30	(Reservations must be made in advance; not available on weekends and on certain other certain other days when there is little demand)
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4. Night lunches are available and consist of sandwiches or microwave box lunch. Please make your orders for night prior to 15:00. Order slips and deposit box are available on the salad bar in the dining room.
5. An open refrigerator and snack bar is maintained in the dining room. Luncheon meat, breakfast cereal, breads, bread spreads, fresh fruit, cookies, juices, sodas, coffee, and tea are all available for your off-meal enjoyment. Frozen TV dinners are available for guests who arrive after the evening meal. Alcoholic beverages are not provided. Any beer, wine, or liquor found in the refrigerators are private stock.
6. Meal service and use of the facilities at Hale Pohaku are limited to authorized personnel. Guests may be accommodated at the request and expense of the host organization. Please provide adequate notification and authorization.

Appendix D

Mountain-top Policies

Observers should at all times abide by the terms of the current safety procedures, as listed below. This list will be occasionally updated in the on-line version of this manual.

1. A telescope operator (TO), who is also a Night Assistant is always assigned to the 2.2-m telescope. The TO is responsible for the control and safety of this telescope and its instruments, and is authorized to close down the telescope or insist that personnel using UH facilities leave the mountain if he believes that weather, an observer's conduct, or other conditions could cause or threaten danger to staff or equipment.
2. Astronomers, assistants, and students are required to spend at least 24 hours in residence at the mid-level facility, Hale Pohaku, before beginning their observing runs. This regulation is designed to insure the safety of both personnel and equipment. Note that individuals may go directly to the summit to work on their own apparatus at their own discretion; the regulation applies to observing. All observers are required to sleep and to eat their main meals at Hale Pohaku.

Further details of the acclimatization requirement may be found in Appendix F.

3. On the day preceding the first night on the 2.2-m telescope, the observer should reconfirm his instrumental requirements with the UH Telescope Superintendent. In the case of instrument changes and balancing, the observer should plan on being at the summit at 10:00 a.m. the day his/her run starts to work out the details with the day crew. Well before 2:00 p.m. he/she should check to see if the equipment desired for the night is installed on the telescope and is in working order. This is especially important the first time a particular instrument configuration is used. Instrument changes and modifications are not readily accomplished once the Day Crew has left the summit at 4:00 p.m.
4. Visiting observers using Institute equipment such as the coudé or Cassegrain spectrographs must satisfy the Director or his designee that they are properly trained to use the equipment. Staff astronomers are not usually available to make special trips to the Observatory for training visitors. In the case of runs involving observatory standard equipment, we will attempt to schedule the visitor after a staff member using the same equipment, so that the visitor can obtain the necessary training by arriving at the Observatory a few days ahead of their scheduled run.
5. Upon their arrival at the summit, the Telescope Operator is required to execute a thorough checklist of building, telescope, and computer functions before commencing an observing run. This procedure permits early identification and trouble-shooting of malfunctions, and will result in more effective use of allocated time.
6. The maintenance staff will assist in emergency equipment repairs but only under direct supervision of the observer. Visiting observers should be prepared to troubleshoot and repair their own equipment.
7. If it is necessary to turn on bright lights in the dome at night, the dome shutter should be closed so as not to interfere with the work of the other telescopes.
8. Clear and legible records are essential for the Observing and Trouble Logs. Users of the smaller telescopes are required to log the number of hours observed, and the weather conditions.
9. Observers are not to carry out changes in the telescope balance, the optical and mechanical alignment of telescopes or instruments, or in the electro-controls; if problems arise, advise the TO.
10. All facilities and equipment must be left clean, and in an orderly state, after each use.

11. First-time users of the 61-cm telescope must spend at least one night learning how to use the telescope from another observer prior to their observing run.
12. Daytime activities, such as copying tapes taken the previous night or preparing observing charts, are the responsibility of the visiting observer.
13. Alcoholic beverages are prohibited on the summit. Telescope Operators are authorized to enforce this policy, and observing time will be withdrawn if the rule is not followed. Personnel scheduled to use equipment at the summit at night must abstain from the consumption of alcoholic beverages during that same day.
14. At the completion of an observing run, observers must rest adequately before driving down to Hilo.

Appendix E

Safety Regulations for observers at UH Telescopes

The following rules are meant to ensure that you have a safe and productive observing run. We ask that all users of UH telescopes abide by them.

1. All observers should have had a recent physical examination in order to ensure that they are not suffering from heart disease or other conditions that could result in health risks at high altitude (the observatory is at an altitude of 4,200 m). Observers should also consult with their physician regarding the effects of high altitude on any medication they may be taking.
2. Observers should familiarize themselves with the symptoms of altitude sickness and inform the telescope operator if any of these symptoms is experienced.
3. A 4-wheel drive vehicle is normally provided at the Hilo airport for observers to drive themselves to the Onizuka Center for International Astronomy (OCIA) at Hale Pohaku, where the observer dining and sleeping facilities are located. Use extreme care when driving on the Saddle Road and the summit road. The Saddle Road, particularly, is narrow and winding in many places, and it is not always safe to assume that oncoming traffic will observe the centerline. There may be heavy rain and fog which reduce visibility and make the road very slippery. The road is windy and hilly which also leads to poor visibility. There is often fast moving oncoming traffic in the middle of the road. *Driving this road may be the most dangerous part of your visit.* First-time visitors may wish to arrange their schedules so that they can ride up and down with the UH Day Crew. In any case, 1.5–2 hours should be allowed for the trip between the airport and OCIA. This is especially important on the way to the airport, where both the temptation and one's ability to drive with excessive speed are particularly dangerous. We strongly recommend obtaining a few hours of sleep after your last night before attempting to drive down.
4. The speed limit between OCIA and the summit is 25 mph, and 4-wheel drive low must be used. Slower speeds are clearly required at blind curves and when visibility is limited by weather conditions. Particularly during the winter months, sections of the road may have ice patches; great care should be taken, especially on the summit switchbacks. Drivers should be aware that the road is frequented by heavy trucks hauling equipment and water, and road grading and other road work is in progress constantly. Wait for safe places to pass large vehicles, and pass road workers slowly to avoid enveloping them in your dust. Excessive speed or other reckless behavior will result in suspension of your driving privileges.
5. Observers are required to spend the night prior to their first night of observing at OCIA in order to acclimatize. Some observers may find that a longer acclimatization is necessary for a comfortable visit. Observers may not work at the summit for more than 16 hours out of any 24 hour period.
6. When driving up or down the summit road alone at night, call the 2.24-m telescope operator before you start up or after you return to OCIA, to ensure that you have not had trouble on the road.
7. Consumption of alcohol is prohibited on the summit at all times, as well as any time within 10 hours before working at the summit.

8. No person should ever be left at the summit without a vehicle, even for a short time. While it is safest if there are always two or more people at a telescope, it is recognized that this will not always be possible at the smaller telescopes. Observers at these telescopes should make arrangements with the telescope operator or some other responsible person to be in regular contact in order to ensure their safety.
9. Observers must leave the summit when instructed to do so by the observatory superintendent or the telescope operator because of weather conditions or for any other reason. The observatory superintendent and the telescope operator also have the final authority over any other matter pertaining to personnel or equipment safety.

Appendix F

Acclimatization—the 24-hour rule

Mauna Kea is arguably the best site on Earth for doing astronomy, but the altitude of the summit, ~14,000ft, is also high enough to induce a variety of physiological disorders. These range from those which are merely uncomfortable, such as breathlessness, nausea, headache, lethargy, giddiness, and insomnia, to those which are life-threatening, viz. pulmonary and cerebral edema.

Virtually all studies of high altitude sickness, as well as the years of experience now accumulated in working on Mauna Kea, indicate that some period of acclimatization at an altitude in excess of ~6,000ft is the single best way to minimize the risk that acute mountain sickness will occur, as well as to ensure that one is able to work with physical and mental abilities minimally impaired. It is largely for this reason that the Mid-Level Facility at Hale Pohaku was established. It is clear both in the medical studies as well as from common experience that, on average, the benefits of acclimatization continue to accrue for several days. As a compromise between the advantages of thorough acclimatization and the time pressures of modern life, experience has shown that 24 hours of acclimatization at Hale Pohaku is a minimum acceptable time to acclimatize before attempting to do a full night's work on the summit. This minimum time of 24 hours' acclimatization for visiting observers has been adopted by virtually every observatory on Mauna Kea.

The formal policy of the Institute for Astronomy is that no member of the IfA staff, or guest observer at a telescope operated by the IfA on Mauna Kea, is permitted to work at the summit for more than six hours without first having acclimatized for a minimum of 24 hours at Hale Pohaku. There are two exceptions to this general rule.

1. Members of telescope crews and road crews who work regular shifts on the mountain are assumed to maintain acclimatization and are exempt from this rule.
2. A person who is acclimatized by working for at least one night on the summit may be considered to retain (a declining) acclimatization for several days after returning to sea level. If such a person wishes to return to work a full night at the summit, he or she will be exempt from this rule provided no more than four days will have elapsed between nights on the summit.

It is emphasized that this requirement should be considered a minimum. Most people find that two nights of acclimatization will prepare them to work at the summit more efficiently and comfortably, and enable them to think more clearly. To some extent it is a matter of learning one's own requirements. For those new to working on Mauna Kea, two nights of acclimatization are highly recommended.

Appendix G

Visitor Information and Costs

G.1 Acclimatization

Institute for Astronomy personnel, and others of greatly different ages and states of health who observe regularly at MKO, have found that reduced oxygen concentration at the summit presents only minor difficulties in their work performance. Experience has led us to establish a pattern for altitude acclimatization to which visiting observers are also required to adhere. As discussed in the Appendix on “Mountain-top Policies,” astronomers, assistants, and students are required to spend at least 24 hours in resting at Hale Pohaku before beginning their observing runs.

A degree of altitude acclimatization is retained by the body on a time scale of days—observers who have spent at least 3 days on the mountain may therefore leave Mauna Kea and spend no more than 3 days at sea level without losing the acclimatization required by Observatory regulations.

Reaction to high-altitude exposure is a very individual matter, and while some symptoms are typical, certain people may experience more or less severe reactions. Astronomers proposing to work at MKO should be in good health and without heart conditions. Anyone having high blood pressure, a respiratory condition, diabetes, or ulcers, or anyone who is pregnant, should consult his or her physician before requesting observing time. In no case can the Institute for Astronomy, the University of Hawaii, or the State of Hawaii be held responsible for adverse high-altitude reactions at MKO.

The first day or night at the summit, after 24 hours of mid-level acclimatization, may result in sleepiness, slight dizziness, generally reduced efficiency, and lethargy. Individuals who have consumed carbonated beverages may feel special discomfort, although not so severe as to prevent working throughout the night. The second night at the summit normally is much easier, with nearly all symptoms reduced or gone. By the third night, individuals rarely feel any discomfort and can function almost routinely.

Those who regularly use the Mauna Kea facilities have found that high-altitude discomfort is reduced if large meals are avoided before going to the summit for a night’s work. Alcoholic beverages demand increased oxygen from the bloodstream (see Appendix D). Smokers normally feel more respiratory discomfort than do nonsmokers.

Because the air at the summit is very dry, observers will normally experience dehydration, generally characterized by dryness of the nasal mucous membranes and throat. Throat lozenges usually relieve this condition. Lip balm is useful for treatment of dry lips. These personal items should be provided by the individual.

G.2 High Altitude Health Tips—How your body functions at high altitude

- **Brain:** High altitude conditions will cause dilation of the blood vessels in and to your brain, increasing your blood flow in order to deliver adequate oxygen. This can lead to pounding migraine-like headaches and occasional vomiting (symptoms of Acute Mountain Sickness) experienced by some people who visit the summit. If you experience this condition, which is usually intensified after exertion, rest is advised along with aspirin or a non-aspirin pain reliever to provide some relief. You can also take altitude medication prescribed by your physician, but you should still be on the alert for impaired decision-making and memory, and impaired mathematical ability. A severe loss of coordination may indicate a more serious effect of high altitude on your central nervous system; this could be associated with cerebral edema, and if you experience this condition, immediate descent is advised.
- **Eyes:** You should be aware that you might experience eye pain and decreased tolerance to light at high altitude, and that you will have decreased night vision. You may also experience a puffiness around the eyes and face. The

dryness of the air, along with the dust, may cause problems for wearers of contact lenses.

- **Skin:** You can experience first and second degree radiation burns after only 15 minutes of unprotected exposure at the summit. Given time, your skin can make enough ultraviolet absorbing pigment to protect itself, but this takes about one week of exposure at 5 minutes per day at the summit. As a precaution, you should protect your skin at all times: wear sunscreen and dark sunglasses in the daytime to filter out ultraviolet rays, watch out for white patches on your nose and ears, and help watch out for other people.
- **Heart:** Your heart's arterial vessels dilate with exposure to high altitude, increasing the flow of blood to the cardiac muscle. To compensate, you should carefully monitor your physical activity and pulse rate, and remember to pace yourself. This is especially true if you have cardiac artery disease, since too much exertion could lead to a cardiac incident. (Be aware, however, that even light exertion at high altitude could increase your pulse rate to more than 100, putting more demand on your heart and cause an increased cardiac workload.)
- **Lungs:** The blood supply to your lungs will increase at high altitude, as will your breathing capacity. Smokers may be more affected by high altitude, so if you smoke, you should not do so for at least the day of your ascent in order to allow the carbon monoxide in your blood to dissipate. Your respiratory rate will also increase, and you could experience lightheadedness and a general tingling sensation from the decreased oxygen and carbon dioxide in your blood. If this occurs, reduce your activity or sit down and lower your head below the level of your heart. The most serious condition you could experience is high altitude pulmonary edema, an accumulation of fluid in your lungs that reduces your lungs' ability to get oxygen into your blood. If you have great difficulty in breathing, along with coughing and a rattling in your chest (like a severe "chest cold"), you should get oxygen if available and descend immediately.
- **Kidneys:** You should drink plenty of water prior to your ascent in order to provide your kidneys with enough fluid to work properly, and to avoid dehydration from pulmonary water losses. Your kidneys will compensate by dumping excess water and sodium, and this will concentrate your blood, hastening your adaptation to low oxygen levels.
- **Bowels:** You should avoid gas-producing foods such as starches, onions, cabbage, etc., as expansion of intestinal gases will lead to flatulence and bowel distension, and may eventually cause pain.
- **Joints:** Breathing at sea-level pressures allows nitrogen gas in your bloodstream to dissipate readily by exhalation; this process is greatly reduced at high altitudes, so you should not SCUBA dive for 24 hours prior to your mountain ascent. If you do SCUBA dive below 50 feet within 12 hours of ascent, you risk formation of nitrogen bubbles in your joints and brain (a dangerous and painful condition known as "the bends"). You should not attempt ascent for at least 48 hours if you have SCUBA dived below 100 feet.

G.3 Mauna Kea Summit Information

G.3.1 Preparing for Severe Weather

If you are planning to join a tour to the summit of Mauna Kea, please remember that you will be traveling to 13,800 feet and should be well prepared. High mountain conditions can change radically in a very short period of time, so we suggest that you prepare for weather that may suddenly deteriorate with 70 mph winds and blowing snow. For your comfort and safety, you should bring the following:

- wool hat;
- mittens or gloves;
- long underwear (tops and bottoms);
- wool sweater;
- long pants;
- wind-proof jacket;
- sturdy walking shoes and wool socks;
- sun screen and lip protection, and,

- dark sunglasses.

Remember: when you plan your visit to the summit, Think Warm! You can always take extra clothes off, but you cannot put them on if you do not bring them.

G.3.2 Preparing for High Altitude

In addition to climatic considerations, the problem of altitude must be addressed. Since you will ascend and descend quickly, long-term effects and severe altitude sickness are not usually problems. However, you will probably feel short-term effects such as light-headedness, shortness of breath, headache, increased frequency of urination, increased flatulence, and dehydration. In order to minimize these potential discomforts, the following precautions are suggested:

- To avoid dehydration, drink as much liquid as possible 24 hours before, during, and for 12 hours after your trip to the summit. Avoid drinking alcohol before the trip, and note that alcohol is not allowed above the 9,000 foot level of Mauna Kea.
- Avoid gas-producing foods the day before and the day of your trip (i.e., beans, starches, cabbage, onions or soft drinks).
- Stop smoking 48 hours before your ascent to allow carbon monoxide in your bloodstream to dissipate; you will need all the oxygen your system can get.
- Do not over-exert yourself at the summit.
- Do not go to the summit within 24 hours of scuba diving.

If you remember these simple steps, you will be able to enjoy your summit tour rather than worrying about freezing fingers or sunburnt lips, and your visit will be both exciting and memorable.

G.4 Visitor Information—Onizuka Center for International Astronomy

The Visitors' Information Station (VIS) is open Friday through Monday year round, as follows:

Friday: 1 p.m. to 6 p.m.
 Saturday: 9 a.m. to 2 p.m.
 Sunday: 9 a.m. to 2 p.m. and 4:30 p.m. to 6 p.m.
 Monday: 1 p.m. to 5 p.m.

A guide is stationed at the VIS during the above hours to assist visitors, lead tours and conduct informational programs. The VIS is closed Tuesday through Thursday, but can be reached at any time by calling (808) 961-2180 for a recorded message on visitor activities and hours.

G.4.1 Official Summit Tours

Every Saturday and Sunday at the summit (8.5 miles above the VIS), the Institute for Astronomy offers a free guided tour beginning at 2:30 p.m. at the University of Hawaii's 88-inch telescope. Those planning to participate should stop at the VIS at least 45 minutes before the tour to get directions and a report on road conditions. The VIS is accessible in conventional automobiles, but anyone traveling to the summit must have a 4-wheel drive vehicle. (*Note:* children under 16 are not allowed on the summit tours because of potentially severe health hazards for young people exposed to high altitude.)

G.4.2 Friday Public Information Night (Introduction to Astronomy)

The Institute for Astronomy conducts an educational program every Friday night at the VIS, consisting of an audiovisual presentation or lecture from 7 to 8 p.m. followed by star-gazing until 9 p.m. (weather permitting). Visitors use the 11-inch telescope at the VIS, and children are encouraged to participate. There is no fee for the program.

G.4.3 Star-gazing from the Summit

Every Saturday night from 6 to 10 p.m., visitors are welcomed to the summit to look at the planets and stars through one of the university's 24-inch telescopes. There is no admission fee, but only 30 people can be accommodated and reservations are required; call Mauna Kea Support Services at (808) 935-3371 between 8 a.m. and 4 p.m. Monday through Friday. Remember that you must have your own 4-wheel drive vehicle and that children under 16 are not allowed to travel to the summit.

G.4.4 Finding Mauna Kea

The access road to the VIS and observatories begins near the 28 mile marker on the Saddle Road (across from the hunter checking station) and leads north to the summit. Travel time to the VIS is about one hour from Hilo or Waimea, and about 1.5 hours from Kailua-Kona.

G.4.5 Caution!

Gas, food and personal supplies are not available on Mauna Kea and weather conditions can become severe in a matter of minutes. Bring plenty of warm clothing to be prepared for possible high winds, freezing fog and snow. Also, remember that the air at the summit is very thin, so pregnant women and people with respiratory, heart and severe overweight conditions are advised not to go higher than the VIS (2800 m elevation). Finally, scuba divers should wait at least 24 hours before traveling to the summit after their last dive.

G.5 Information and Costs for Visiting Observers at UH Telescopes

This section contains important information regarding the pricing and operations policies applicable to use of University of Hawaii Telescopes by visiting observers. Please read this information carefully to avoid any possible future misunderstandings.

The Institute for Astronomy of the University of Hawaii accepts unsolicited proposals for study of Solar system objects with its 2.2-m telescope on Mauna Kea. However, we are not primarily a visitor facility, and visitors must understand that we do not offer the level of support that one might expect at NOAO or the IRTF. It is essential that anyone who accepts time on UH telescopes is an experienced observer.

In most cases, we assume that visitors have used similar instrumentation elsewhere and will have studied any documentation we have been able to supply prior to their arrival. *It is the responsibility of the observer to ensure that he or she is familiar with the instrumentation before their observing run.*

The summit of Mauna Kea is 4,200 meters above sea level, and we require that all observers on UH telescopes spend the night prior to their first night of observations at the mid-level facility at Hale Pohaku in order to begin acclimatizing to the altitude.

G.5.1 Direct Costs

Although telescope time which has been awarded to visitors by our Time Allocation Committee is granted without charge, we must pass on certain direct costs. These normally include the costs of room and board, vehicle expenses, consumables such as liquid nitrogen and/or helium (including transportation costs), and any technical help with visitor equipment beyond mounting it to, and dismounting it from, the telescope.

Room and Board—The University of Hawaii has assured access to six dormitory rooms at Hale Pohaku, which are billed to us as used at the standard rate set by MKSS. One of these rooms is always reserved for the telescope operator, and the remaining rooms are allocated according to our priority list (below). In most cases, we can rent additional rooms as necessary, but in this case MKSS bills us at a higher rate, and we are forced to pass on these additional charges if incurred by visitors.

Priority List—By imposing some restrictions on our scheduling, we can guarantee accommodations to up to two current observers on the 2.2-m Telescope and one observer on the 61-cm telescope.

Additionally we can usually accommodate up to two scheduled 2.2-m observers and one scheduled 61-cm observer for *one* acclimatization night immediately preceding their runs. Observers falling in these categories will be charged the standard rate set by Mauna Kea Support Services (currently \$80 per day, but subject to change).

In most cases, when observing groups exceed these limits in number or duration of stay, we will be able to arrange to rent additional rooms from other agencies, but will then have to pass on costs at the higher rate (currently \$106 per day) charged by MKSS. Visiting observers must understand however that accommodations for those not falling within the UH room limit *cannot be guaranteed*.

G.5.2 Vehicles

2.2-m observers travel to the summit with the Telescope Operator (TO) in a 4-wheel drive vehicle, which is also made available to them during the day for the purposes of checking equipment.

A single observer using a 61-cm telescope for only a few nights can usually arrange to ride with the TO and 2.2-m observer(s), but must be willing to adjust to the 2.2-m schedule.

A dedicated 4-wheel drive vehicle will normally be required for 61-cm runs with more than one observer, or of more than a few days in length, or for those involving special time constraints. Because we have only a limited number of vehicles, we normally require observers on the 61-cm telescope to rent their own 4-wheel drive vehicle. A list of rental agencies and their current cost is given in Appendix A. Visitors will be billed for gasoline used by a rented vehicle.

Under normal circumstances we will provide one vehicle per observing run for transportation from the airport in Hilo to Hale Pohaku. Observers for the same run should coordinate their schedules and inform our Hilo office so that they can all go together; if this is impossible, the extra observers should plan to rent a car or make special arrangements to go up with the UH day crew.

University vehicles are to be used only for transportation between the airport and Hale Pohaku, or between Hale Pohaku and the summit of Mauna Kea. They are not to be used for touring expeditions. Any use beyond those stated must be approved in advance by the Telescope Superintendent or, if he cannot be reached, by the telescope operator.

G.5.3 Cryogenics

It is most economical to purchase LHe in the 30, 60 or 100 liter dewars supplied by Gaspro, and LN₂ in the 160 liter dewars owned by UH. Visiting observers using cryogenics will be billed following their observing run for the amounts they ordered, or used, whichever is greater. LHe is very expensive. The current cost of LN₂ is \$4.00 per liter, and \$2.25 per pound for dry ice. Observers using facility instruments are normally charged for 10 liters of LN₂ per night. These prices are subject to change without notice.

G.5.4 Visitor Equipment

Visiting observers bringing their own instruments are responsible for supplying any mechanical or electrical interfaces required. Bolt circle patterns and design focus positions are given in Chapter 6; further details can be obtained from Andrew Pickles [(808) 974-4205]. Electrical and electronic interface information can be obtained by contacting Ken Maesato at the summit [(808) 974-4200]. It is expected that visitors will be prepared to handle any technical problems occurring with their own equipment. Any assistance by UH staff beyond mounting and dismounting visitor equipment will depend on the availability of personnel and will be charged to the visitor's account at standard rates, including overtime if applicable.